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<b>14. ABSTRACT</b> The object of this work is the compilation of all the available data on the action of phosgene on man and the laboratory animals. This includes data obtained in the laboratory and in the field. The information herein contained has been obtained from American, British and French reports. The British and French reports were not all available; as a consequence only a part of the British and French work is here presented. The first part of this report deals with laboratory tests while the second part is a compilation of the various field tests conducted by the Americans and British on phosgene and mixtures. Phosgene has been designated as CG, G-52, D-Stoff, carbonyl chloride, carbon oxychloride, collongite, MD-8, L-3. A glossary of pathological terms, together with a discussion of methods of obtaining concentrations and other toxicological methods referred to in this report is given in E.A.C.D. 105.						
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A DIGEST OF REPORTS CONCERNING

THE TOXIC EFFECT

of

PHOSGENE

on

MAN AND THE LABORATORY ANIMALS.

By:

M. D. CRAIGHILL

and

R. E. MORSE.

MAY, 1922

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I. INTRODUCTION.

The object of this work is the compilation of all the available data on the action of phosgene on man and the laboratory animals. This includes data obtained in the laboratory and in the field. The information herein contained has been obtained from American, British and French reports. The British and French reports were not all available; as a consequence only a part of the British and French work is here represented.

The first part of this report deals with laboratory tests while the second part is a compilation of the various field tests conducted by the Americans and British on phosgene and mixtures.

Phosgene has been designated as CG, G-52, D-Stoff, carbonyl chloride, carbon oxychloride, collongite, AD-8, L-3.

A glossary of pathological terms, together with a discussion of methods of obtaining concentrations and other toxicological methods referred to in this report is given in E.A.C.D. 105.



## II. SUMMARY.

### **A. SYMPTOMATOLOGY OF PHOSGENE POISONING:**

Phosgene acts as a respiratory irritant, penetrating to the terminal air cells of the lungs. The symptoms which arise are those chiefly due to want of oxygen due to impaired functioning of the air cells. In addition, there is lachrymation, salivation and nasal discharge. After exposure, the smell of the gas remains subjectively for several hours.

The symptoms noted upon exposure to low concentrations are: Irritation of the respiratory passages, coughing, dyspnoea, constriction of the chest and lachrymation. These symptoms later decrease and disappear.

Exposure to high concentrations usually produces rapid, shallow and labored breathing, burning pain in the chest, nausea, retching and vomiting. This is followed by headache and asphyxial symptoms (respiratory paroxysms ending with gagging and frothy mucus from the mouth. There may be extreme restlessness and anxiety or semi-coma and delirium. The blood shows an increase in haemoglobin, due to increased concentration of red corpuscles. X-ray examinations shows dilatation of the right heart. Broncho-pneumonia frequently occurs on the fourth or fifth day due to secondary infection. This is accompanied by increased fever and a purulent sputum.

The gas has a curious characteristic effect upon the taste, causing the odor of tobacco smoke to be very unpleasant.

One of two common types of symptoms are frequently exhibited in cases of phosgene poisoning. The predominant type is characteristic by an ashen pallor; the lips are leaden colored; respiration is rapid and shallow with indications of intense oedema of the lungs; coughing is frequent; the pulse is 130-140 per minute, weak and runny; and general collapse follows. In the other type there is distension of the superficial veins of the face, neck and chest. The lips and tongue are blue; breathing is deeper and more rapid. There may be a cough with expectoration of thin fluid; the pulse is 100 per minute, full and with good tension.

Symptoms of phosgene poisoning seldom occur immediately, and death may suddenly occur after an interval during which no sign of injury was observed. Very often an incapacity for exertion exists which is one of the most marked effects of the gas.

The course of the disease is largely dependant upon the activity of the patient after being gassed. Exposures to high concentrations followed by complete rest and plenty of fresh air have often led to recovery whereas exposures to lower concentrations followed by exertion have often resulted in death.

Death usually occurs within the first three days and may be very sudden. Secondary infection may cause death even after a month or more.

In the case of dogs dying acutely, the temperature rises to a maximum coincident with the increased blood concentration. The temperature then falls suddenly and the animal dies.

When dogs survive the acute period the temperature arises to a maximum but the fall is slow and it gradually returns to normal.

#### Bibliography:

B.M. XVIII 90, 8, and 10; B.M. XIV 63; B.M. XIII 138;  
B.M. VII 50;  
P.T. VIII A386-A391, A398; P.T. II A127;  
M.Ph. 29  
A.E.P. 48;  
G - 5;  
Ph. 20; Ph. 21; Ph. 36; Ph. 37; Ph. 55; Ph. 75; Ph. 87; Ph. 114;  
Z - 30-36; Z - 30-37; Z 30-39; Z 30-42; Z 30-44; Z 275;  
H.D.D. 46; H.D.D. 56;  
Ph. 97; Ph 98;  
A.P.M. 34A.  
Correspondence Files- CD-138.

#### B. PATHOLOGY OF PHOSGENE POISONING:

##### 1. Respiratory System:

###### a. Upper air passages.

Little affected, nasal and pharyngeal mucosa moderately hyperaemic.

b. Larynx.

Hyperaemic, necrosed and exfoliated, mucosa. Fragmentation and fracture of muscle fibers, especially of posterior cricoarytenoids and transverse arytenoids.

c. Trachea.

Congestion of blood vessels, dilation of lymphatics, oedema of mucosa. Frothy serous fluid, sometimes bloody. Constriction by intra-flexion of the posterior segment where the cartilage ring is interrupted.

d. Bronchi.

(1) Large and medium sized.

Epithelial lining intact; lumina filled with mucopurulent exudate; increase in goblet cells.

(2) Small.

Appear constricted; desquamation of ciliated epithelium; a layer of newly formed flattened cells; filled with desquamated epithelial cells or occasionally with organizing mass or newly formed vascular connective tissue; fibroblastic proliferation in the walls.

e. Lungs.

(1) Death within 2 hours.

Lungs small, heavy, purple, airless, water clogged. No emphysema, thin serous fluid.

(2) Death in 24 hours.

Lungs voluminous, heavy, oedematous; congested with blood, extreme dilatation of vessels; alternating emphysema and atelectasis; frothy serous fluid with dark blood from cut surface; sometimes petechial haemorrhage on surface; terminal air cells filled at end of 12-20 hours with sero-fibrinous exudate.

(3) Death in 2 - 3 days.

Similar to first day deaths; aeration of lungs greater; less fluid; pulmonary oedema reaches maximum within first 72 hours; and may ultimately disappear.

(4) Death in 4 days.

No fluid dripping from cut surface; beginning of broncho-pneumonia and often pleurisy; pneumonia may be associated with necrotization of the walls of the bronchioles, with abscess formation in the alveoli; destruction of elastic tissue; alveolar cavity filled with epithelial cells, erythrocytes and polymorphs.

(5) Death after 10 days.

Sterile pneumonia.

(a) Pleura.

Slight fibrous thickening; dilatation of lymphatics.

(b) Pleural Cavity.

Sometimes considerable pleural effusion which may be blood stained.

2. Blood Vascular System:

(a) Heart:

(1) Changes following gassing.

First stage - dilatation

Second stage - shrinkage

Third stage - engorgement

(2) Gross Pathology:

Left ventricle solid.

Right ventricle - flabby and dilated, muscle yellowish.

(3) Microscopic Pathology:

Cardiac walls; some degeneration of fibres; occasional fat vacuoles; muscle fibres granular, atrophic in places, hypertrophic in others; oedema and congestion; subendocardial hemorrhages.

Pericardium: Vessels dilated; lymphatics distended;  
slight fibrous thickening of pericardium.

(b) Blood:

First Stage - Increased volume, due to influx of fluid from  
the tissues, decrease in solids.

Second Stage - Decreased volume, due to passage of fluid  
from the lungs; increased in solids and probably increase in viscosity;  
decreased oxygen carrying capacity; thrombosis in lungs and some other  
organs.

Third Stage - Return to normal.

(c) Spleen:

Malpighian corpuscles some atrophic, others hyperplastic,  
pulp distended with red blood cells, lymphocytes, fat vacuoles mononuclears;  
Hemosiderin in pulp; excessive normoblasts in splenic sinuses; some  
increase in fibroblasts; capsule normal.

3. Alimentary Tract:

(a) Salivary Glands.

Large, clear mucous cells with nucleus displaced to side;  
filled with amorphous, shiny, mucigenous substance.

(b) Oesophagus.

Superficial layers of mucous exfoliated into wide lamella;  
in the submucosa, oedema and imbibition causing detachment from muscle;  
diffuse hyperemia.

(c) Stomach.

Some oedema and congestion of mucosa.

(d) Intestines.

Some congestion of blood vessels.

(e) Liver.

Central atrophy and degeneration of secreting cells; marked  
vascular dilatation and congestion.

4. Excretory System: (Kidneys)

(a) Glomeruli:

Albumin precipitated in glomerular capsule; desquamation of epithelial lining of Bowman's Capsule; epithelium sometimes granular and hyaline.

(b) Tubules:

Epithelium swollen and granular; parenchymatous and fatty degeneration; occasional hyaline casts.

(c) Interstitial tissues:

Oedematous.

5. Glands of Internal Secretion:

(a) Adrenal:

Normal.

(b) Thyroid:

Marked variation in size of acini, colloid only in large cells.

6. Eyes:

Purulent conjunctivitis.

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B.M. XVIII- Report #8  
B.M. X - Report #61  
B.M. XXI-76  
P.T. VIII-2 - 337  
H.D.D. 3  
Ph. 2, A.B.F. 48-95  
Ph. 194  
Ph. 17, Ph. 21, Ph. 40, Ph. 46, Ph. 50, Ph. 76, Ph. 96.  
Z.30-12, Z.30-34, Z.30-36, Z.85-A.  
H.D.D. 46, H.D.D. 56.

# C. TOXICITY:

## 1. Man:

Odor is perceptible at 0.0044 mg./l. - H.H.D. 3; Ph. 4.

The lowest concentration detected by mouth, throat or lower respiratory tract:

Concentration mg./l.	Time of exposure Seconds	Subjects Positive	Reference
0.015	Average 42	6/9	B.M. IX-35
0.25	Not given	Not given	P.R. V-220

Irritation of eyes, nose and throat at 0.044 mg./l. H.H.D. 3  
Ph. 1.

Maximum concentration which can be breathed without immediate distress 0.035 mg./l. 45 observers exposed - Ph. 1.

Irritation of eyes - 0.0354 mg./l. - Ph. 1

Intense irritation of eyes - 0.442 mg./l. - Ph. 1.

Conjectural figures:

Minimum effective concentrations:

Concentration mg./l.	Time of Exposures Minutes	Reference
2.21	0.5	Ph. 1
0.88	5.0	Ph. 1
0.02208	30.0	H.H.D. 3

## 2. Lethal Concentrations:

(a) For Dogs:

### Summary of Data.

Concentration mg./l.	Time Minutes	Died/Exposed	Reference
4.415	1	Not given	Ph. 189
2.208	5	" "	Ph. 189
1.6	3	" "	B.M. XXIV-86
1.15	7.5	4/16	Ph. O.D. 101
0.893	12	Not given	Ph. 189
0.46	15	" "	B.M. XXIV-86
0.29	30	6/8	B.M. XXXII-57
0.31-0.36	30	23/29	B.M. XIX-74
0.4415	30	Not given	Ph. 189
0.33	30	" "	B.M. XXIV-86
0.14	120	" "	B.M. XXIV-86
0.024	240	3/4	B.M. XXXII-57

The following points were taken from a smooth curve constructed upon the results obtained by the Americans and the British on the lethal concentration of phosgene for dogs at various times of exposure. The time times concentration value has also been calculated.

Lethal Concentration Mg./l.	Times of Exposure Minutes	Time x Concentration Minutes x Mg./l.
4.42	1	4.42
2.85	2	4.70
1.65	3	4.95
1.30	4	5.16
1.08	5	5.38
0.62	10	6.22
0.46	15	6.90
0.38	20	7.55
0.29	30	8.70
0.17	60	10.20
0.14	120	16.80
0.028	240	5.76

(b) For Mice.

Conc. Mg./l.	Time in Min.	Died/Exposed	Reference
0.442	1 - 5	Not given	Ph 1
0.4	10	100%	P.T. II-A 127
0.081	30	100%	B.M. XXXII-57
0.163	60	100%	Ph 77

(c) For Rats.

Conc. Mg./l.	Time in Min.	Died/Exposed	Reference
0.88	3	Not given	GVN XXII-Ft3
0.04	30	100%	B.M. XXXII-57
0.163	60	100%	Ph 77
0.02	240	100%	B.M. XXXII-57



## (d) Rabbits:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
0.77	10	Not given	Ph. 1
0.22	60	" "	"
0.025	80	" "	B.M. XXXII-57
0.01	240	100%	"

## (e) For Cats:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	1	Not given	Ph. 189
2.208	2	" "	Ph. 189
0.883	5	" "	Ph. 189
1.6	8	" "	C.W.M. vol. XXII, pt. III
0.4416	10	" "	Ph. 189
0.2208	30	" "	Ph. 189
0.22	30	" "	C.W.M. vol. XXII, pt. III
0.22	60	" "	H.D.D. -3
0.1635	60	2/3	Ph. 77

## (f) For Goats:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	1	Not given	Ph. 189
2.208	3	" "	Ph. 189
2.2	3	" "	C.W.M. vol. XXII, pt. III
0.883	10	" "	Ph. 189
0.4416	30	" "	Ph. 189
0.44	30	" "	C.W.M. vol. XXII, pt. III

## (g) For Guinea Pigs:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	0.5	Not given	Ph. 189
2.208	1.	" "	Ph. 189
0.883	3	" "	Ph. 189
0.88	3	" "	C.W.M. vol. XXII, pt. III
0.4416	4	" "	Ph. 189
0.2208	10	" "	Ph. 189
0.0883	20	" "	Ph. 189
0.08	30	" "	C.W.M. vol. XXII, pt. III
0.073	30	2/2	B.M. XXXII-57
0.0918	60	3/3	Ph. 17
0.02	240	3/4	B.M. XXXII-57

(h) For Monkeys:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
2.208	1	Not given	Ph. 189
0.883	3	" "	Ph. 189
0.441	3	" "	Ph. 189
0.44	3	" "	C.W.M.vol.XXII,pt.III
0.2208	6	" "	Ph. 189
0.0883	20	" "	Ph. 189
0.08	30	" "	C.W.M.vol.XXII,pt.III
0.041	240	2/2	B.M. XXXII-57

The foregoing tables have been compiled from a number of sources and figures from different references are not comparable. The following notes apply to the references given and may afford some idea of their value.

Ph. 189: No information is given on nature of tests. It is not known whether any attempt was made to determine accurately a lethal concentration. The report was given for the purpose of bringing out broad distinctions between animals. The time of death is not indicated.

Ph. 77: The time of death was less than 24 hours. These are experimental data. Three concentrations were used, too widely variant to establish a lethal concentration.

B.M. XXIV-36: The lethal concentration was taken as that concentration which killed 70-80% of the animals within ten days. The source of the data and method of making the tests were not given.

B.M. XXXII-57: These are experimental data. The time of death was less than 48 hours and the tests were made in a continuous flow chamber, the concentration being determined by analysis.

B.M. VII-60: The figure given by Marshall and Hanson was decided upon by them after experiments on 25 dogs. Two dogs were used at each concentration. No details of the work are given.

C.W.M. XXII-part III: The data are taken from an English report and concentrations are given as those which were "required to kill at the given time."

PT-II-A127: The time of death was less than 48 hours. These are experimental data. Concentrations were obtained by aeration and determined by chemical analysis.

B.M. 3: The source of the data given is not known.

### III. DOGS.

#### A. SYMPTOMATOLOGY.

The following symptoms were observed during field tests, and one laboratory test which is noted. The symptoms may be roughly divided into groups, according as they are exhibited at exposures which caused death, (1) during exposure, (2) after exposure but before eight hours, (3) after eight hours but before fifteen days, and (4) those from which the dogs recovered. In the field tests definite concentrations were not known and exposures lasted thirty minutes. In the laboratory test exposures were for thirty minutes, concentrations between 0.6 and 1.2 mg./l. causing death before eight hours and concentrations between 0.15 and 0.6 mg./l. causing deaths after eight hours.

1. Dogs dying during Exposure: P.E. VIII-A 385 - A 388.

Symptoms at concentrations causing death during exposure: Three out of seven dogs exhibited marked cyanosis in addition to the symptoms given in (3).

2. Dogs dying before 8 hours: P.E. VIII-A 386 - A389.  
B.M. VII-50 (Laboratory Experiment)  
B.M. XCVIII-90-8 (B.M. XIX-76)  
B.M. XIV-83-b

Symptoms at concentrations causing death before 8 hours: Fifteen dogs in field tests showed rapid and shallow respiration, gasping and coughing, salivation, nasal discharge, lachrymation, depression, tracheal rattles, irregular heart action.

Six dogs in laboratory test at concentrations between 0.6 and 1.2 mg./l. for thirty minutes exhibited slight lachrymation, unconsciousness, clouded pupils. No violent symptoms were observed and vomiting was rare.

3. Dogs dying between 8 hours and 15 days: P.E. VIII-A386 - A389  
B.M. VII-50 (Laboratory Experiment)  
B.M. XCVIII-90-8 (B.M. XIX-75)

Symptoms at concentrations causing death after 8 hours and before 15 days: Twenty dogs in field tests showed depression, dyspnea, salivation, ocular inflammation, coughing, retching, rapid and shallow breathing, conjunctivitis, vomiting.

Nineteen dogs in a laboratory test at concentrations from 0.15 to 0.6 mg./l. for thirty minutes showed lachrymation and restlessness. Nine of these died.

4. Dogs which recovered: P.T. VIII-A 386 - A388 - A 389.  
B.M. XXVIII-90-8 (B.M. XXIX-75)

Symptoms at concentrations from which dogs recovered are given: Fourteen dogs classified as light casualties showed slight lachrymation, slight nasal discharge, moderate depression, coughing, difficult breathing.

Three dogs classified as severe casualties showed marked depression, muscular weakness, ocular inflammation, nasal discharge, coughing, shallow and labored respiration.

B. PATHOLOGY:

B.M. XVIII-90-8 (B.M. XIX-75)  
Ph. 86, 44, 46, 194.

**L. Lungs:**

The lungs contain serous material which takes either a homogeneous or granular pink stain. Edema is present especially in sub-pleural alveoli. In animals succumbing in 12-22 days the alveoli are small with high cubical epithelial cells and large mononuclear leucocytes. Atelectasis and emphysema are found. In the case of dogs dying after 10 days, pneumonia is the direct cause.

2. **Heart:**

Dilatation of the right ventricle is found and occasionally of the left ventricle and auricle but usually the left heart is firm. The muscle is usually pale, occasional vegetative growth occurs on the mitral valve and amongst the chordae tendineae. The blood vessels are usually well injected; there is an occasional hemorrhage under the endocardium.

dilatation of vessels, inflammation, thickening of the capillary wall, atrophy or hypertrophy of muscle or presence of fat vacuoles.

3. Sploer:

The spleen is slightly enlarged. The pulp is distended with red blood cells and hemosiderin is in the pulp.

4. Alimentary Tract:

Occasionally there is a congestion of the mucosa.

5. Liver:

Dark brown patches are found around the hepatic vein which is always engorged; the portal vein is sometimes engorged; Very rarely necrosis or inflammatory reaction is found.

6. Peritoneal Cavity:

No excess fluid but engorgement of vessels is found.

7. Excretory System:

The kidney has a dark cortex. In animals succumbing in 5 to 6 days, cloudy swelling, congestion of glomeruli, and fatty degeneration are found.

8. PHYSIOLOGY:

Phosgene at a concentration of 1.48 mg./l. was bubbled through defibrinated dogs blood for five minutes. A definite darkening of the blood was produced in three minutes and at the end of five minutes there was almost complete agglutination of the red blood cells with definite haemolysis. Haemolysis was complete in 15 minutes at room temperature. The lower concentrations require longer exposures to obtain the above results.

The following stages in pulmonary oedema are observed:

(1) Increased volume due to influx of fluid, probably from tissues, resulting in a decrease of the blood solids; (2) reduced blood volume, due to passage of fluid from blood to lungs, increase in blood solids, development of pulmonary oedema. (These various stages are indicative of time and degree of pulmonary change; (3) period of readjustment - return to normal.

1. Lungs:

The water content increases progressively in the lungs. There is no noticeable change in the water content of the muscle, which indicates that muscle tissue does not give up water to the blood during the lung oedema.

2. Eyes:

At high concentrations (1 to 5 mg./l.) for 1 hour intense conjunctivitis and lachrymation occurs. The cornea is intact.

### 3. Blood:

The arterial blood pressure shows a slight rise about 2 hours after gassing. It then drops to its previous level and is maintained at this point up to the period of clinical signs of lung involvement. At this stage there is a second rise which terminates in a fall immediately before the death of the animal. The venous blood pressure shows little variation until just before death when there is a slight rise.

The blood volume is unchanged until pulmonary symptoms appear. At this time there is a decided decrease. The red blood cell count increases with the volume decrease.

There is first a decrease in the concentration of the blood accompanied by a decrease in the chloride and oxygen content. After this initial decrease there is a great increase during which the chloride and oxygen content return to normal.

The coagulation time was 8 to 10 minutes four hours after the gassing. The normal time is usually 3 to 5 minutes. No change has been observed in the alkaline reserve. No decrease in fibrinogen is established.

### 4. Oedematous Fluid:

Comparison with Plasma: The transudate resembles plasma very much and lymph still more. It contains the fundamental elements. Its percentage of water coagulable albumin, freezing point, alkalinity, percentage of chlorides, phosphates and cholesterol approach that of blood. The non-protein nitrogen, urea, ammonia and glucose are higher than in the plasma. The phosphorus and carbonate content is greater than in the blood.

### 5. Urine:

After the inhalation of phosgene there is a functional disturbance in the secretion of urine as shown by the fall of the maximum concentration of urea. This drop is considerable in the fatal cases. The urea excretion is constantly lower after severe cases of gassing which shows that the capacity for excretion has been decreased. The chloride excretion remains unchanged, the ammonia excretion is probably disturbed. In fatal cases there is always an increase in ammonia and total nitrogen. This is not the case after less severe gassing. There is an exaggerated elimination of phosphates.

References:

B.M. XXI-76  
B.M. XIII-138  
M.Ph. 28-29.  
Ph. - 46, 75, 97, 114 - App VI-b.  
Z - 30-12, 30-36, 30-39, 32-11 & 295.

D. TONICITY:

(1) Ph. 36.

Summary of experiments on chronic phosgene poisoning.

Conc. Gr./L.	Time of Exposure Minutes	Result Death in
4.410	11	10½ hrs.
4.410	12	4 "
2.884	10	9 "
2.205	30	8½ "

Criticism: Only four concentrations which were accurately known were abstracted from this report. There were not enough dogs used at any one concentration or at one time of exposure to warrant definite conclusions. H.A.K.

(2) Ph. 189.

The times of exposure necessary to produce ultimate death are given as:

Concentration Gr./L.	Time of Exposure Minutes
4.410	1
2.205	3
0.882	12
0.441	30

Note: These results are given, along with lethal concentrations on other animals, only to bring out certain broad distinctions between different animals. They are not final.

(3) C.M.M. XIII-P. M. III.

Concentration required to kill at stated time.

Concentration	Time
Mg./l.	Minutes
2.2	5
0.68	15
0.44	30

Criticism: This is an extract from the original data and its precise meaning is not clear. H.A.K.

(4) Groesbeck and H.G. Witherspoon.  
E.A.C.D. #101.

The lethal concentrations of phosgene for dogs for  $7\frac{1}{2}$  minutes exposure.

Conc. Mg./l.	Deaths in 24 hours	Deaths between 24-48 hrs.	Deaths between 2-10 days	Total Deaths	Total Percent Deaths in 10 days
1.52-2.11	1/2			1/2	50
1.38-1.43	3/4		1/4	4/4	100
1.27-1.36	2/5	1/5	1/5	4/5	80
1.15-1.23	3/6	1/6	1/6	5/6	83
1.08-1.15	4/6			4/6	67
0.98-1.05	1/2			1/2	50

The lethal concentration of phosgene for a  $7\frac{1}{2}$  minute exposure on dogs is placed at 1.1 mg./l. or 275 ppm.

Criticism: This work was done carefully and should be as accurate as any data available. H.A.K.

(5) Miller and Gross.

E.A. XXIII-57.

Minimum lethal concentration of phosgene for dogs.

Exposure: 30 minutes.



Concentration mg./l.	Died/Exposed	Time of Death in hrs.
0.44	2/2	12, 28
0.38	2/2	lost, 24
0.35	2/2	10, 14
0.29	6/8	5, 9, 13, 21, 22, 288
0.28	3/4	19, 19, 32
0.19	0/2	
0.18	1/2	16
0.17	1/3	12

Exposure: 4 hours.

Concentration mg./l.	Died/Exposed	Time of death in hrs.
.054	4/4	6, 6, 6, 27
.03	3/4	9, 32, 108
.024	3/4	31, 43, 120
.019	2/4	66, 214
.016	0/4	
.008	0/5	

The lethal concentration is taken as 0.29 mg./l. for thirty minutes exposure; and 0.024 mg./l. for four hours exposure.

(6) F.S. Underhill.  
B.M. XIX-74.

Toxicity of Phosgene on Dogs.

Time of Exposure: 30 minutes. Concentration determined by chemical analysis.

Concentration mg./l.	No. of dogs	% Acute Deaths 1-3 days	% Delayed Deaths	% Total
0.40-0.45	29	62	3	65
0.36-0.40	30	67	13	80
0.31-0.36	29	69	10	79
0.27-0.31	30	42	12	54

(7) Marshall and Hanson.  
B.M. VII-50.

Toxicity of phosgene on dogs.

Concentration Mg./l.	Time of Death Hours
1.11	3 - 7
1.10	4
1.00	4 - 7
0.84	4 - 7
0.75	7 - 15
0.64	7 - 15
0.55	Survived
0.51	6 - 15
0.47	6 - 15
0.44	24 - 36
0.44	20
0.40	Survived
0.35	Survived
0.35	Survived
0.31	24
0.31	Survived
0.27	6 - 15
0.23	Survived
0.22	24 - 36
0.22	24
0.19	Survived
0.15	24 - 36
0.12	Survived
0.12	Survived
0.11	Survived

One dog was used in each test. 0.55 mg./l. was taken as the lethal concentration for exposure of 30 minutes.

Three dogs gassed at 0.35 and 0.4 m./l. survived. It seems that 0.44 mg./l. would be a more reasonable figure than 0.35 mg./l. for the lethal concentration.

(8) Marshall.  
B.M. I-29.

The figures given in this report of preliminary work are included in those given in B.M. VII-50.

(9) Ph. 1.

0.276 mg./l. for 30 minutes exposure is fatal in 48 hours.

(10) Marshall.

B.M. XXIV-86.

Preliminary report on the relation between lethal concentration and time of exposure.

Concentration <u>Mg./l.</u>	Time of Exposure <u>Minutes</u>
1.6	3
0.46	15
0.33	30
0.14	120

Criticism: The source of these figures is not indicated.  
The lethal concentrations are those which kill  
about 80% of the dogs in ten days. E.A.K.

#### IV. MICE.

##### A. SYMPTOMATOLOGY:

There is very little to be found on the symptomatology of mice. Dyspnoea is a common manifestation.

##### B. PATHOLOGY:

(1) M.Ph. I.  
ph. 40.

###### (a) Gross Findings:

On autopsy, mice show accentuated rigor mortis, indicating lack of oxygen in the blood. The buccal, pharyngeal and laryngotracheal mucous membranes are hyperaemic. Subepithelial hemorrhage is found.

The lungs and bronchi have a variegated aspect, large deep red areas alternating with normal. They present a bloody surface, hyperaemic on section, and vessels clogged with blood. The mucosa of the large bronchi is detached.

In the trachea the mucosa is hyperaemic, less intense, however, than in the larynx; there is constriction by intorflexion of the posterior segment where the cartilage ring is interrupted.

###### (b) Microscopic Findings:

The mucopharyngeal mucosa is moderately hyperaemic.

In the salivary and submaxillary glands, there are large, clear mucous cells with nuclei displaced to the side of the cells; the glands are filled with amorphous shiny mucilaginous substance.

In the oesophagus, superficial layers of mucosa are thrown into wide lamellae; the submucosa is oedematous. Inhibition causing detachment of muscle is found. There is diffuse hyperaemia.

In the larynx the mucosa is necrosed, exfoliated and ruptured. There is a true necrotic inflammation. Fragmentation of muscle is similar to diphtheria. Fibers are fractured transversely in irregular fragments with ends split or jagged. The post cricoarytenoid and the transverse arytenoid muscles are especially affected probably from the convulsive opening and closing of the larynx.

C. PHYSIOLOGY:

(1). M.Ph. 1.

Mice exposed for forty minutes to a concentration of 0.4416 mg./l. show no large quantity of gas (above 1%) absorbed into the blood. A large quantity would permanently destroy the coloring matter of the blood, but this is not the case after gassing with phosgene.

D. TOXICITY:

(1) Ph. 1.

Certain gasses and vapors and their physiological effects.

Concentration Mg./l.	Time of Exposure Minutes	Effect
0.442	1 - 5	Fatal in 24 hours
0.088	15	Had little or no effect
0.055	15	Was not fatal, but
		oedema was produced.
0.044	6	May be fatal in 6 hrs;
		oedema and congestion
0.022	30	May be fatal in 48 hrs.

Criticisms: No definite decisions are reached. H.A.K.

(a) Miller and Groos.  
B.M. XXIII-57.

Toxicity of phosgene on small animals.

Time of exposure: 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.21	5/5	16, 16, 16, 24, 36
0.19	5/5	16, 16, 24, 24, 24
0.15	5/5	16, 16, 16, 40, 64
0.125	5/5	24, 48, 48, 72, 120
0.12	0/5	
0.036	4/5	48, 48, 48, 96
0.031	5/5	44, 40, 120, 196, 216
0.077	2/5	44
0.073	4/5	48, 48, 48, 72
0.043	1/5	90, 238
0.040	0/5	
0.034	1/5	96, 264, 260
0.032	2/5	72, 120
0.028	0/5	

The lethal concentration for thirty minutes exposure was taken as 0.073 mg./l.

Criticism: The individual times given in the third column do not check with the data given in the second column at 0.034 mg./l. and at 0.43 mg./l. R.E.H.

Exposure: 4 Hours.

Concentration mg./l.	Died/Exposed	Time of death in hours
0.029	5/5	18, 18, 18, 24, 40
0.020	5/5	18, 18, 72, 72, 72
0.020	5/5	18, 18, 18, 18, 18
0.010	5/5	18, 18, 18, 40, 216
0.008	5/5	48, 48, 48, 192, 192

The minimum lethal concentration was taken as 0.008 mg./l. for 4 hours exposure.

Criticism: Work should have been done at concentrations below 0.008 mg./l. to establish this point as the lethal concentration. H.A.K.

(3) Ph. 77.

Lethal Concentration of Phosgene.

Exposure: 1 hour

Deaths in 24 hours.

Concentration mg./l.	Died/Exposed
0.433	3/3
0.163	3/3
0.021	1/3

Criticism: Data are insufficient to establish the lethal concentration. H.A.K.

(4) Kuhn and Cohn.  
P.T. II, A-127.

Lethal Concentration for mice at ten minutes exposure.

Concentration mg./l.	Died/Exposed in 48 hrs.	Total percent died
2.5	2/3	100
1.5	3/3	100
1.0	2/3	100
0.8	3/3	100
0.7	3/3	100
0.4	3/3	100
0.35	1/3	53
0.3	0/6	00
0.2	1/3	53
0.15	0/3	00

0.4 mg./l. is taken as the lethal concentration of phosgene for white mice at ten minutes exposure.

Y. RATS.

A. SYMPTOMATOLOGY:

Ph. 58.

Slight uneasiness, salivation, lachrymation, occasional gasping, dyspnoea, retching, clonic convulsions of hind legs and sudden collapse.

B. PATHOLOGY:

Ph. 58, 77.

H.D.D. 45.

The lungs are usually shrunken, firm and of an elastic consistency. The upper lobes and sloping portions of the middle and lower lobes are usually dark brown-red in color with subpleural and marginal interstitial emphysema. The pleural cavity and pericardium may contain free serum.

C. TOXICITY:

(1) Ph. 189.

The times of exposure necessary to produce ultimate death, are:

<u>Concentration</u> <u>Mg./l.</u>	<u>Time of Exposure</u> <u>Minutes</u>
4.426	1/2
2.208	2
0.883	3
0.442	5
0.221	10
0.088	25

This is preliminary work.



(2) R. Mueller.

Ph. 56. (Taken from Ztscher. Exp. Path. Therap. 9,103, - 25).

Concentration mg./l.	Time of Exposure Minutes	Result
22.00	15	Death in 4 hours 20 minutes
8.82	14	" " 1 " 7 "
2.21	5	" " 5 " 11 "
1.09	20	Recovered
1.09	5	Died over night
0.54	15	Recovered

Criticism: Only one rat was used in each test. Benzene vapor of a concentration about  $4\frac{1}{2}$  times that of the phosgene was used throughout. This makes it difficult to draw conclusions. H.A.K.

(3) C.W.M. XXII - Part III.

Concentration necessary to kill.

Concentration mg./l.	Time of Exposure Minutes
0.88	5
0.06	30

Rat exposed to a concentration of 0.27 mg./l. for 30 minutes survived 5 hours.

Criticism: This is probably an abstract from Dr. Barcroft's report given in full in Ph. 189. H.A.K.

(4) Miller and Gross.  
B.M. XXIII-57.

Lethal concentrations for rats with exposure of 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.21	2/2	16, 16
0.19	2/2	16, 16
0.15	2/2	16, 24
0.123	2/2	20, 20
0.120	2/2	16, 16
0.086	3/4	18, 18, 18
0.081	2/2	16, 16
0.077	1/2	18
0.073	2/2	48, 48
0.043	1/2	48
0.040	2/2	18, 18
0.034	0/2	
0.032	0/2	
0.025	1/4	96

Criticism: This report is very good. The lethal concentration for 30 minutes exposure may be placed at 0.04 mg./l. H.A.K.

Exposure: Four hours..

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.029	2/2	16, 16
0.020	4/4	18, 18, 18, 18
0.020	2/2	13, 18
0.010	0/2	
0.008	0/4	

Criticism: A concentration should have been established between 0.01 and 0.02 mg./l. H.A.K.

(5) Ph. 77

Lethal concentration of phosgene on rats t.

Number of deaths in 24 hours for one hour exposure.

Concentration Mg./l.	Died/Exposed
0.163	3/3
0.091	2/3

Criticism: The work is too limited to be of much value.  
The lowest concentration for one hour exposure  
is twice the 30 minute figure reported by  
Lt. Miller in B.M. XXXII-57. H.A.K.

## VI. RABBITS.

### A. SYMPTOMATOLOGY.

There is very little literature on the symptoms produced when rabbits are exposed to phosgene. The only symptoms noted were lachrymation and conjunctivitis.

### B. PATHOLOGY.

The pathology of rabbits dying from phosgene poisoning is practically the same as that of mice and that section should be consulted for this data.

### C. PHYSIOLOGY.

2. 30-2; . 3. 30-44.

There is an early rise in the number of red blood cells and the amount of haemoglobin per cubic centimeter of blood within a few hours after exposure. This is due to concentration of the blood-oligemia which persists one to two days. The second stage, secondary rise, type polycythemia may persist many weeks.

Inhalation of phosgene causes a quick fall in pulmonary ventilation and a notable diminution in the oxygen consumption and carbon dioxide production. This phenomenon lasts only with the duration of inhalation. There is a quick fall just before death. If the inhalation is not fatal, the ventilation returns to its original level. The above phenomenon is of reflex nature but not influenced by general anaesthesia. It is caused by the passage of gas into the upper respiratory passage alone and the intensity is equal to that when inhaled in the lungs also.

The following of the irritant gas into the deep respiratory passages, without passing through the upper respiratory passage does not cause diminution of ventilation. It is able on the contrary, to cause an augmentation of the ventilation. This augmentation is of a reflex nature and is not necessarily accompanied by an augmentation of the exchanges.

The last phase period or the antemortem fall of ventilation and the exchanges are not nervous reflexes but correlative with the establishment of a pulmonary lesion.

D. TOXICITY.

(1) Ph. 1.

Concentration mg./l.	Time of Exposure Minutes	Results
0.770	10	Death in 4 hours
0.520	20	Usually fatal
0.442	20	Not fatal
0.290	15	" "
0.221	30	" "
0.221	60	Fatal
0.176	30	Generally not fatal

Criticism: The lethal concentrations given by the British in Ph. 1 and Ph. 109 are considerably higher than those obtained in the U.S. H.A.K.

(2) Barcroft.  
Ph. 189.

Concentration mg./l.	Exposure in minutes to produce ultimate death.
4.416	7 - 10
2.208	7 - 10
0.893	10 - 15
0.442	30

Criticism: Report is not specific enough. H.A.K.

(3) C.B.M. XIII - pt. III.

Concentration mg./l.	Time required to kill Minutes
0.83	15
0.44	30

Criticism: Data are from English Reports and are insufficient for reliable conclusions. H.A.K.

(4) H.D.A. 46.

Two rabbits were exposed for 30 minutes to a concentration of 0.1472 mg./l. One died in 7 hours, the other in 5 hours.

Criticism: No minimum lethal concentration was established. H.A.K. These figures were only incidental to the main feature of the report, i.e. cause of acute oligæmia and true polycythæmia. M.G.

(5) Miller and Gross.  
B.M. XXXII-57

Method - Continuous flow.  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

<u>Concentration</u>		<u>Died/Exposed</u>	<u>Time of death</u> <u>in hours</u>
0.21	:	2/2	: 16, 16
0.19	:	1/2	: 192
0.15	:	2/2	: 48, -?
0.123	:	2/2	: 120, 240
0.120	:	2/2	: 96, 120
0.086	:	2/4	: 192, 120
0.081	:	2/2	: 96, 96
0.077	:	2/2	: 72, 144
0.073	:	2/2	: 120, 48
0.043	:	1/2	: 144
0.040	:	2/2	: 148, 192
0.034	:	2/2	: 96, 216
0.032	:	2/2	: 72, 120
0.025	:	4/4	: 120, 168, 96, 96

0.025 mg/l. takes as minimum lethal concentration for a 30 minute exposure.

Criticism: A concentration below 0.025 mg/l should have been established and tested. H.A.K.

Exposure: 4 Hours

<u>Concentration</u> mg/l	:	<u>Died/exposed</u>	:	<u>Time of death</u> in hours
0.029	:	2/2	:	120, 120
0.020	:	3/4	:	144, 24, 120
0.020	:	1/2	:	72
0.010	:	2/2	:	72, 120
0.008	:	1/4	:	168

0.010 mg/l. taken as minimum lethal concentration for a 4 hour exposure.

Criticism: This is a complete accurate report.  
H.A.K.

(6) H.D.S. 3.  
Ph. 66

0.0736 mg/l. exposure for 1 hour causes death within 24 hours.

Criticism: This figure is three times that established by Miller for 30 minutes exposure. H.A.K.

(7) Ph. 77

Exposure 1 hour, death in 24 hours.

<u>Concentration</u> mg/l	:	<u>Died/ Exposed</u>
0.433	:	3/3
0.1635	:	0/3
0.0918	:	0/3

Criticism: The lowest lethal figure given in this report  
is six times that given for the same exposure  
in another British Report H. D.D. 3 or Ph. 66.  
H.A.K.



### VII. CATS.

#### A. SYMPTOMATOLOGY:

Ph. 40, 58.

The only symptoms noted in the available literature are cyanosis, dyspnoea and retching.

#### B. PATHOLOGY:

Ph. 40, 58, 77.

There is very little available literature on the pathology of cats poisoned by phosgene. There have been found pulmonary oedema, interstitial emphysema, corroded gastric and duodenal mucosa with haemorrhagic areas.

#### C. PHYSIOLOGY:

H.D.D. 58.

Experiments on urine.

The acidity of urine from cats gassed at a concentration of from 0.05 - 1.7 mg./l. reaches a maximum on the 4th day after gassing. The return to normal is slow.

The coefficient of Robin falls until the 4th day, after which there is a slow and regular rise to normal.

Phosgene gives a distinctly different curve for acidity of urine than chlorine or hydrocyanic acid, with which it was compared. This suggests a possible method of diagnosis.

#### D. TOXICITY:

(1) Barcroft.  
Pg. 189.

Concentration Mg./l.	Exposure in minutes to produce ultimate death.
4.416	1
2.208	2
0.883	5
0.442	10
0.221	30

Criticisms: The constant relation between time and concentration for the first four concentrations is very remarkable.  
H.A.K.

(2) Ph. 1.

Report upon certain gases and their physiological effects.

Concentration Mg./l.	Exposure Minutes	Result
0.390	10	Fatal in 18 hours
0.221	20	Usually fatal in 5 hours
0.110	30	May be fatal in 12 hours
0.088	20	Not fatal
0.074	30	Not fatal

Criticism: Data are insufficient to enable drawing of conclusions. H.A.K.

(3) G.W.M. XIII part III.

Concentrations required to kill at stated time.

Concentration Mg./l.	Time Minutes
1.6	5
0.22	30

Criticism: This is not original data. Exact meaning is not clear. R.E.M.

(4) H.D.D. 2.

12 hours.

Cats exposed 1 hour to concentration of 0.2300 died within

(5) Ph. 77.

Exposure - 1 hour  
Deaths in 24 hours.

Concentration Mg./l.	Deaths
0.433	3/3
0.164	2/3
0.092	1/3

(6) J.H.M. 35.

3 inch shell containing 600 cc. phosgene exploded in chamber of 254 cub. m. capacity.

Theoretical concentration - 3.25 mg/l.

Three cats:

#1	on floor	died	2½	hours.
#2	1 m. from floor	"	5	"
#3	2 m.	"	6½	"

## VIII. GOATS.

### A. SYMPTOMATOLOGY:

P.E. VIII, A 385.

lachrymation, depression, nasal discharge and retching were noticed during a field test, from which the goats recovered.

### B. PATHOLOGY:

This is covered in a general way in the chapters on the pathology of dogs, cats and other laboratory animals.

### C. PHYSIOLOGY:

Ph. 37.

The degree of oxygenation of venous and arterial blood in goats gassed with phosgene is shown in three stages; arterial and venous blood normally oxygenated; arterial blood normally oxygenated, venous blood deficient in oxygen; both arterial and venous blood deficient in oxygen.

The onset of poisoning appears not as deficient oxygenation of blood in lungs but as increased reduction of blood in capillaries.

There is evidence of obstruction to circulation in the lungs.

### D. TOXICITY:

(1) Ph. 1, 2

Concentration Mg./l.	Exposure Minutes	Results
2.21	3	Minimum fatal concentration
1.00	3	Not fatal
0.77	10	Fatal in 24 hours
0.38	10	Not fatal

(2) Barcroft.  
Pl. 189.

Concentration Mg./l.	Exposure to produce ultimate death minutes
4.416	1
2.208	5
0.883	10
0.442	80

(3) O.W.M. XIII - part III.

Concentration Mg./l.	Time required to kill in stated time minutes
2.2	5
0.44	80

Criticism: Not original data. Exact meaning not clear.  
R.E.K.

IX. GUINEA PIGS.

The (A) symptomatology, (B) pathology and (C) physiology sections are omitted here and on monkeys because of scarcity of data.

D. TOXICITY:

- (1) Barcroft.  
Ph. 189.

Concentration Mg./l.	Exposure in minutes to produce ultimate death
4.416	0.5
2.208	1.
0.883	5.
0.4416	4.
0.2208	10.
0.0883	20.

Criticism: The four minute and twenty minute concentrations are apparently low. H.A.K.

- (2) C.W.M. XXII - part III.

Concentration Mg./l.	Required to kill at stated time minutes
0.88	5
0.08	30

A guinea pig exposed to a concentration of 0.27 mg./l. survived four hours and thirty minutes.

Criticism: Does not state where figures were obtained. Meaning is not very clear. H.A.K.

(8) Miller and Gross.  
B.M. XXXII-57.

Method - continuous flow.  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.21	2/2	16, -16
0.19	2/2	16, -16
0.15	2/2	16, -16
0.125	1/2	6
0.120	2/2	16, -16
0.088	3/4	18, 18, -18
0.081	2/2	18, -72
0.077	2/2	6, -24
0.073	2/2	18, -18
0.043	0/2	
0.040	0/2	
0.034	0/2	
0.032	0/2	
0.025	0/4	

0.073 mg./l. is taken as minimum lethal concentration for a 30 minute exposure.

Criticisms: This is a complete report and apparently accurate. H.A.K.

Exposure: 4 hours.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.029	2/2	18, -18
0.020	3/4	168, -18, -18
0.020	0/2	
0.010	0/2	
0.008	0/4	

0.020 mg./l. is taken as minimum lethal concentration for a 4 hour exposure.

Criticisms: To be absolutely conclusive, 0.02 mg./l. should be tested again. H.A.K.

(4) H.D.D. 3, Ph. 2, Ph. 66.

0.2209 mg./l. exposure for one hour caused death in 12 hrs.

Criticism: The British in Ph. 189 reported the same figures for a 10 minute exposure. H.A.K. This is not given as the minimum lethal concentration. R.E.K.

(5) Ph. 77.

Exposure one hour, death in 24 hours.

Concentration mg./l.	Died/Exposed
0.433	3/3
0.1635	3/3
0.0918	3/3

Criticism: Concentration below 0.09 mg./l. should have been tested to establish a definite minimum lethal concentration. H.A.K.



I. MONKEYS.

A. TOXICITY:

- (1) Barcroft.  
Ph. 129.

Concentration Mg./l.	Exposure in min. to produce ultimate death.
2.208	1
0.883	3
0.4416	3
0.2208	6
0.0883	20

Criticisms: Sufficient data is not given to establish the lethal concentration for 3 minutes. H.A.K.

- (2) U.W.M. XXII - part III

Concentration Mg./l.	To Kill at stated time Minutes
0.44	3
0.08	30

Criticisms: Report does not state where figures were obtained. Thirty minute figure is twice that obtained by Miller. H.A.K.

- (3) Miller and Gross.  
B.M. XXVII-57.

Method - continuous flow  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.061	4/4	10, -10, -10, -45
0.046	2/2	12, -16
0.041	2/2	10, -10
0.035	1/2	48.
0.030	1/2	18.
0.017	0/2	

0.041 mg./l. taken as the minimum lethal concentration for a 30 minute exposure.

Criticisms: A conclusive report. H.A.K.

PH. MAN.

A. SYMPTOMATOLOGY:

A.E.F. 66.  
A.E.F. 48 - G-5.  
Ph. 17, 40, 53.  
A.P.M. 34, A No. 7.

Phosgene acts as a respiratory irritant, penetrating to the terminal air cells of the lungs. The symptoms which arise are those chiefly due to want of oxygen due to impaired functioning of the air cells. In addition, there is lachrymation, salivation and nasal discharge. After exposure, the smell of the gas remains subjectively for several hours.

The symptoms noted upon exposure to low concentrations, are: Irritation of the respiratory passages, coughing, dyspnoea, constriction of the chest and lachrymation. These symptoms later decrease and disappear.

Exposure to high concentrations usually produces rapid, shallow and labored breathing, burning pain in the chest, nausea, retching and vomiting. This is followed by headache and asphyxial symptoms (respiratory paroxysms ending with gagging and frothy mucus from the mouth. There may be extreme restlessness and anxiety or semi-coma and delirium. The blood shows an increase in haemoglobin, due to increased concentration of red corpuscles. X-ray examinations shows dilatation of the right heart. Broncho-pneumonia frequently occurs on the fourth or fifth day due to secondary infection. This is accompanied by increased fever and a purulent sputum.

The gas has a curious characteristic effect upon the taste, causing the odor of tobacco smoke to be very unpleasant.

One of two common types of symptoms are frequently exhibited in cases of phosgene poisoning. The predominant type is characteristic by an ashen pallor; the lips are leaden colored; respiration is rapid and shallow with indications of intense oedema of the lungs; coughing is frequent; the pulse is 130-140 per minute, weak and runny; and general collapse follows. In the other type there is distension of the superficial veins of the face, neck and chest. The lips and tongue are blue; breathing is deeper and more rapid. There may be a cough with expectoration of thin fluid; the pulse is 100 per minute, full and with good tension.

Symptoms of phosgene poisoning seldom occur immediately, and death may suddenly occur after an interval during which no sign of injury was observed. Very often an incapacity for exertion exists which is one of the most marked effects of the gas.

The course of the disease is largely dependent upon the activity of the patient after being gassed. Exposures to high concentrations followed by complete rest and plenty of fresh air have often led to recovery whereas exposures to lower concentrations followed by exertion have often resulted in death.

Death usually occurs within the first three days and may be very sudden. Secondary infection may cause death even after a month or more.

## 2. Ph. 21.

On general lines the symptomatology for phosgene is similar to symptomatology for chlorine, but the manner of onset is different. After an initial sensation of intense suffocation with constriction of thorax and sensation as though the heart had stopped, the man who has breathed phosgene apparently recovers completely. After 6 to 24 hours (usually 10-12) the recovery seems complete. Then suddenly, on occasion of physical effort or passing from heat to cold, or slight digestive trouble, the patient is seized by acute oedema of the lungs and dies sometimes in a few minutes. In the light cases which are in the majority, there is development of pulmonary emphysema with sensation of suffocation and increased arterial tension. These sick men neither cough nor spit. When death does not occur at once the prognosis is generally good and recovery in 8 to 10 days with about the same chance of late broncho pulmonary complications as with chlorine. The same asthenia and loss of weight occurs.

## B. PATHOLOGY.

In studying the pathological aspect of phosgene poisoning on man, it must be remembered that the data have been collected from reports on battle casualties, and that there were probably no cases of purely phosgene poisoning under battle conditions. Phosgene, in cloud attacks, was mixed with chlorine, and the two gases are, to a large degree, similar in action. The principal effects of phosgene and chlorine appear to be due to their asphyxiant action, along with local poisoning and corrosion.

Ph. 17.

An autopsy was performed on a man who died eight days after gassing. The white matter of both cerebral hemispheres was found to contain large numbers of perivascular hemorrhages, uniformly distributed. The corpus callosum contained many hemorrhages. A part of the dorsal cord showed hemorrhages in the white matter.

Ph. 20.

Hemorrhages of the white matter of the brain occur in large numbers of acute cases of gas poisoning; more frequently from phosgene than from chlorine. The breaking down of the lungs may be said to be the principal feature in poisoning by asphyxiant gases.

Criticism: This report consists of a general discussion of phosgene poisoning and does not go into details.

Ph. 40.

In this report are described the findings of a number of autopsies on soldiers dying from the effects of asphyxiant gases, but whether the gas was phosgene or chlorine or, more probably, a mixture is not stated. Congestion and oedema of the lung and respiratory system are the outstanding features, though almost all the organs may be injured.

A. B. 66.

Post mortem findings on chloring and phosgene poisoning.

In cases of death at 24 hours after gas poisoning, the trachea and bronchi are purple red and congested, while a thin exudate wells up into them from the lungs. The latter organs are heavy and oedematous, while aerated islets of emphysematous over distension alternate with depressed purple patches of collapse. On section, serous fluid drips abundantly from the lung tissue. Air that has escaped from ruptured vesicle is seen in chains of bubbles on the surface of the lungs, along the interlobular fissure and even penetrating the tissue of the mediastinum. In some of the earliest cases, the most intense disruptive emphysema may be observed destroying the air sacs and interfering with the circulation of their walls.

Petechial hemorrhages appear on the surface of the lungs, on the heart, and also on the inner surface of the stomach. All the veins are greatly distended and the abdominal viscera are engorged with dark red blood that clots very early after death. The heart itself may fail to show right side dilatation, for this does not of necessity appear after death in cases of asphyxiation.

If the man succumbs at a later date, inflammatory complications appear in the lungs. There is superficial pleurisy, scattered bronchopneumonia and a purulent secretion in the bronchi. The serous exudate will then be found to have disappeared and no fluid drops from the cut surface of the lungs.

#### D. PHYSIOLOGY:

Changes in the blood of rabbits, following exposure to phosgene. From Physiological Laboratories, Cambridge, England.

Experiments with rabbits exposed to a concentration of 0.1472 mg/l for 30 minutes showed that there was an early rise in the number of red blood corpuscles (acute oligemia). This rise persists for 1 - 2 days. There is also a secondary rise, a true polycythemia, which may persist for many weeks.

The cause of the acute oligemia, is the loss of water from the blood, causing a concentration of the corpuscles. By experimentation, it was found that there was an average increase of 17% in the number of red blood cells, within 3 hours after exposure to a concentration of 0.1472 mg/l. It was also determined that there was a diminution of approximately 15% in the total volume of blood. This was determined by bleeding the rabbit from the carotid.

By macroscopic and microscopic examination of the lungs, it was found that the oligæmia had a definite relationship to the amount of pulmonary oedema produced by the gassing.

Other factors contributing to oligæmia were found to be diminution in the fluid content of the blood, generalized tissue oedema due to increased osmotic pressure of the tissues caused by lack of oxygen, outflowing of fluid into the alimentary canal, and an outpouring of adrenaline.

True polycythaemia starts about the 9th day. It may persist as long as 8 weeks. In such cases, there is no pulmonary oedema. The condition indicates a definite stimulation to the bone marrow, due to the deficiency of oxygen. Experiments on convalescent animals placed in a chamber containing a high percentage of oxygen, showed that chronic polycythaemia could be temporarily abolished by exposure to the increased oxygen.

#### C. TOXICITY:

(1) Sherwood and Snyder, B.M. IX-38.

To determine the smallest concentration of phosgene which can be detected by mouth, throat, and lower respiratory tract.

Conc. : mg/l	Total #:	Posi-: Tests	Doubt-: tive	Neg.: tests	Doubt-: tests	Time of Pos. : Tests in Sec.	Time of Neg. : Tests	Time of Doubt-: Tests	Aver.
0.000:	8	0	0	8	0	-	-	-	-
0.004:	9	1	0	8	0	50	50	50	-
0.008:	10	2	3	3	2	35	60	41	-
0.015:	9	6	2	1	0	28	60	42	-
0.025:	14	12	2	0	0	10	60	32	-

(29) Ph. 4.

Experiments to determine personal factor in testing box respirators.

The subjects in the following test were familiar with gas.

Mouth breathing - Eyes protected				Nose breathing - Eyes exposed			
Breaking down :	No.	% of	No. : conc. mg./l. Subjects : tested	Breaking down :	No.	% of	No. : conc. mg./l. Subjects : tested
0.01766	5	8		0.01336	1	5	
0.0286	1	5		0.01766	5	14	
0.0353	17	49		0.01766	12	54	
0.04416	5	8		0.04416	1	5	
0.05503	7	20		0.06608	12	34	
0.05898	2	6		0.05898	2	6	
0.08803	2	6		0.08803	1	5	
Total - - - - -	35			Can stand stronger than 0.08803	1	5	
				Total	86		

The subjects in the following test were not accustomed to gas.

Mouth breathing - Eyes protected				Nose breathing - Eyes exposed			
Breaking down :	No.	% of	No. : conc. mg./l. Subjects : tested	Breaking down :	No.	% of	No. : conc. mg./l. Subjects : tested
0.008802	1	12.5		0.00802	1	12.5	
0.017604	3	37.5		0.01336	1	12.5	
0.035208	2	25		0.017604	2	25	
0.04416	2	25		0.035208	1	12.5	
Total - - - - -	8			0.04416	3	37.5	
				Total - - - - -	8		

The maximum concentrations (43 persons tested) which could be breathed for 3 minutes without serious discomfort varied from 0.008832 mg./l. to 0.08832 mg./l. About one-half of the subjects found 0.0354 mg./l. to be the limiting concentration.

Criticism: The "breaking down concentration" is apparently the concentration which was unbearable for a period of 3 minutes, but this is not clearly indicated. R.E.M.

(3) H.D.D. 3.

A concentration of 0.044 mg./l. produced irritation of eyes, nose and throat with cough after 5 minutes; odor perceptible at 0.0044 mg./l. The conjectural figure given for minimum effective concentration is 0.88 mg./l. and for maximum safe concentration 0.02208 mg./l.

(4) Ph. 1.

Irritation of eyes produced at 0.0254 mg./l. Intense irritation at 0.422 mg./l.

Conjectural figures:

Maximum tolerable concentration

2.21 mg./l. for 0.5 minutes exposure

0.88 mg./l. for 5.0 " "

Minimum lethal concentration for a 30 minute exposure, about 0.1104 mg./l.

The maximum safe concentration for a 12 hour exposure was 0.0044 mg./l.

(5) P.R. Y-220.

With eyes and nose protected the minimum concentration which can be detected by the throat and respiratory tract was found to be 0.25 mg./l.

(6) Ph. 13.

0.02208 mg./l. makes sojourn in air impossible.

(7) C.C.P. 6064 (#148).

Experiments on the "Fatigue of the sense of smell".

Eight observers exposed to a concentration of 0.00088 mg./l. for 2 min.; odor was very perceptible, only one thought intensity of odor diminished; 4 complained of irritation of eyes.

Conclusions: There is apparently no fatigue of the sense of smell in the case of phosgene.

Note: In working with phosgene in the Toxicological Laboratory at Edgewood Arsenal it has been found that phosgene does produce fatigue of the sense of smell. R.E.M.



## XII. ADMIXTURES.

### (1) P.T. VIII A-351.

Toxicity on dogs, Phosgene and Mustard.

A mixture of 80% mustard, 20% pure phosgene at 29°C. produced death on dogs in a slightly less time than 90% mustard and 20% crude phosgene at 20°C.

Criticisms: The report is vague and inconclusive.

### (2) Mayer Z-607.

On the toxicity of a mixture of mustard gas and phosgene on dogs.

Mixture 50 cc = 72.8 gm. phosgene  
48.5 cc = 68.2 gm. mustard gas

(a) 3 dogs used at each concentration in the following test.

Concentration Mg./l.	Exposure minutes	Resultant Deaths	Resultant deaths if mustard gas had been used separately.
0.50	15	1/3	all
0.50	5	0/3	some (1/3 for phosgene)
0.25	30	1/3	all
0.25	5	0/3	-
0.10	30	0/3	-

Note: The histological lesions on the animals used in these experiments seem less severe than those produced by pure phosgene.

(b) 1 dog used in each test.

Concentration Mg./l.	Exposure Minutes	Result
0.50	30	Died after 4 days
0.50	5	Killed after 5 days
0.50	50	Died after 5 days
0.25	50	Killed after 5 days
0.25	5	Killed after 5 days
0.10	30	Killed after 5 days

Conclusion: Mixtures of mustard gas and phosgene (50% of each) are less toxic than pure mustard gas or pure phosgene.

Criticism: There seems to be too little data to entirely justify the conclusion. R.E.M.

(5) Martin, Searle and Dallwig.  
S.M. XXVII-84, (12).

Mixture of mustard gas (80-85%) and phosgene (20-15%)  
Toxicity on dogs.

Method: Phosgene was displaced in flask by concentrated sulphuric acid to obtain concentration and checked by analysis. Two gases were mixed and run into gassing chamber. Ventilation of gassing chamber: 250 l/min. mustard gas concentration calculated by loss in weight method.

Exposure: 30 minutes.

Concentration mg./l.				Delayed	Total	Recover-	%
Mustard: Phosgene	No.	Acute	Deaths	gas	ies in	gas	
Calc: Calc: AmL.	Dogs: Deaths	No. of	deaths	two	Deaths		
			days		Weeks		
0.08 : 0.01: 0.01	2	0	14, 14	2	0	100	
0.07 : 0.01: 0.003 (?)	2	0	5	1	1	50	
0.06 : - : 4-01	10	0	5, 5, 14	3	6	30	
1 : 4-07x			10				
1 : 2-10x			(other				
1 : 1			cause):				
0.05 : 0.01: 2-006	8	0	11, 8, 6	3	5	37 1/2	
0.04 : 0.01: 0.01	4	0	0	0	4	0	

x - First runs with flowmeter. Accuracy of concentration questionable.

Conclusions:

1. Lethal concentration of mustard with 15-20% admixture of phosgene - 0.05 to 0.07 mg./l.
2. Efficiency of mustard is diminished by admixture of phosgene, as shown by the results, that there were no acute deaths and there was an increase of 5 days in average time of death over the corresponding time for pure mustard.
3. There is an apparent direct antagonism between mustard gas and phosgene.

Criticism: This checks Dr. Mayer's conclusion. H.A.K.

(4) Kruse and Dallwig.  
P. 3 VII A-348.

#### Toxicity on Dogs.

Mixture of mustard gas (average 75%) and  
phosgene, chlorine free, (average 25%).

Method: Mustard gas was aerated by the usual method. Phosgene was displaced with concentrated sulphuric acid. The gases were mixed and drawn into the gassing chamber. Ventilation of chamber 150 - 250 l./min. Chemical analysis was made for total chlorides. The mustard gas concentration was checked by subtracting the nominal phosgene concentration.

Exposure: 30 minutes.

Mustard gas conc. mg./l.	No. Dogs	Delayed Deaths Days	True Mustard Gas Deaths	Recover- ies in 2 weeks	% Mustard Gas Deaths
0.17	2	4, 6	2	0	100
0.08	4	8, 6, 12, 4	4	0	100
0.07	4	5, 4, 12	3	1	75
0.06	4	10, 5, 9, 9	4	0	100
0.05	4	6	1	3	25
0.04	8	9, 8, 5	3	5	37
0.03	10	5, 4, 4, 12	3	6	30

#### Conclusions:

1. The lethal concentration of mustard gas with 25% phosgene is 0.05 mg./l.
2. There is no advantage from the toxicological standpoint in using the mixture.

(5) C.L. 18 (A.G. 21)

Mixtures of chlorpicrin (3 pts. approx.) and phosgene (1 pt.) were breathed (eyes exposed) by 10 subjects. Phosgene had no influence on the lachrymatory powers of chlorpicrin.

(6) 2-550, vol. 1.

Second International Gas Conference. 3-5-18.

Phosgene and Chlorpicrin - (Phosgene 48.3; Chlorpicrin 51.7)

Inhaled - 30 minutes.

Mixtures not more toxic than their constituents.

(Phosgene - 50%

German Green Cross 11 Shell (Trichloromethyl chloroformate - 30%

(Chlorinated Arsine - 20%

Properties -

(a) Sternutatory action - concentration 2 mg./l., 1 mg./l.  
0.25 mg./l. for man and animals.

(b) Action on skin uncertain - none noted on animals.

(c) Respiratory irritant properties - suffocant upper passages -  
concentration 0.03 mg./l., deeper passages - concentration 0.2 mg./l.

(d) Effect of inhalation - Toxicity

Lethal conc. for dog - 0.5 mg./l. - 15 min.

1 mg./l. - 5 min.

(7) 2-53-A

Extract from the Official Report of the Session of

Jan. 23, 1918 - Ministry of Armament.

On the toxicity of liquids extracted from enemy shell.

Test of two enemy shell containing

Phosgene - 48.5%

Chlorpicrin - 51.7%

Toxicity of inhaled mixture was tested.

Method: Vaporization with compressed air in 13 cu. ft.  
chamber. Each test on 8 dogs of from 20 to 15 kg. weight.

Exposure: 30 min.

Results: Conc. mg./l.

	Died 20 hrs. after
1.0	" 24 " "
	" 48 " "
	Died 24 hrs. after
0.5	" 48 " "
	" 48 " "
	Died 4 days after
0.25	Survived

"

constituents. Conclusions: The mixture is not more toxic than its

(8) Kruse and Dallwig.  
P.T. VIII A-353.

Toxicity on dogs.

Mixture of 50% phosgene (chlorine free)  
50% cyanogen chloride (purified)

Method: Cyanogen chloride was aerated in the usual way and immersed in an ice bath kept at 0°C. Phosgene was run into chamber by displacement with concentrated sulphuric acid. The gasses went through mixer, then into gassing chamber. Ventilation of chamber 250 l./min. Chemical Analysis: Total chlorides, cyanogen chloride. Checked by subtracting nominal phosgene figures.

Exposure time: 30 minutes.

Results:

Total Conc. mg./l.	No. Dogs	Acute Deaths Hours	Delayed Deaths Days	Total True Deaths	Recovered Days	Percent Deaths
0.90	2	20 min. 20 min.	0	2	0	100
0.41	2	7, 31	0	2	0	100
0.36	2	19, 8	0	2	0	100
0.32	4	17, 13	13*	2	14	50
0.31	2	30, 42	0	2	0	100
0.29	2	0	0	0	18, no record	0
0.25	4	1 in 43 mins.	0	1	19, 19, 19	25
0.23	2	0	0	0	19, 19	0
0.22	2	1 in 14 hrs.	0	1	20	50
0.21	2	0	13*	0	14	0
0.14	4	0	0	0	14, 14, 14, 14	0

\*Death not due to gassing.

Conclusions:

1. Lethal concentration - 0.15 mg./l. of each gas.  
Note: Series with cyanogen chloride alone showed deaths at 0.15 mg./l.
2. To produce deaths with mixture, one of gases must be present in lethal concentration.

(9) Kruse and Delling.  
P.T. VIII A-244.

Toxicity on Dogs.

Mixture of 50% Arsine  
50% Phosgene (chlorine free)

Method: Arsine was run into chamber by displacement with a saturated solution of sodium chloride; phosgene run into chamber by displacement with concentrated sulphuric acid; gases mixed before introduction into gassing chamber; ventilation of chamber 250 l./min.

Exposure: 30 minutes.

No chemical control analysis was run as the displacement method is very accurate.

A total of 20 dogs was used.

Results:

Total Conc. Mg./l.	No. Dogs	Acute Deaths Hours	Delayed Deaths Days	Total Gas Deaths	Recovered in 2 Weeks	Percent Gas Deaths
0.40	4	2 Deaths 28, 9	4-1/3	4	0	100
0.39	2	0	0	0	2	0
0.37	2	0	0	0	2	0
0.36	2	1 in 18 hrs.	0	1	1	50
0.31	2	0	0	0	2	0
0.28	2	0	0	0	2	0
0.27	2	28, 46	0	2	0	100
0.21	2	0	0	0	2	0
0.20	2	0	0	0	2	0

Conclusions:

1. Lethal concentration mixture 0.4 mg./l. a little higher than either alone. (arsine — 0.3 mg./l.; phosgene 0.35 mg./l.)
2. Only advantage — more acute death.

XIII. FIELD TESTS.

1. H.A. Kuhn, P.T. VIII - A-588.  
Richter, Burrell and Oglesby, B.M. XX-63.

Report on phosgene fired statically in Livens projectiles.

a. Object: To determine the concentrations, limits of cloud and toxic area for dogs and goats in a double line of trenches using phosgene in Livens projectiles and to find how the concentration varies with time.

b. Method:

1. One Livens drum containing 11,880 cc. (36.67 lbs) of phosgene (90.75% pure) was fired statically 30 ft. from first trench. The distance between first and second trench was 37-1/2 feet.

2. The booster had a 1/8" groove, 3/8" wide, machined to its full length. 6 oz. black powder was used with a squib.

3. Animals used (exposure 30 minutes.)

(a) Seven goats at 20 ft. intervals with dog between goats at either end of first trench.

(b) Nine goats at 30 ft. intervals with dog between last two goats at either end of second trench.

c. Meteorological Data:

October 8, 1918, 11.00 A.M.  
Weather - clear.

Wind velocity at firing, 3.5 miles per hour.  
Average for 5 minutes, 4.2 miles per hour.

Temperature of air - inside trench	56°F.
" " " - outside "	55°F.
" " ground - inside "	46°F.
" " " - outside "	47°F.

Relative humidity - inside trench	71%
" " outside "	70%

Barometer - 29.95 inches.

Direction of wind - at time of firing, right angles to center row of goats. It suddenly shifted to the right carrying most of the gas to the right of trenches. Cloud was higher in air than usual and only part of it settled in the trenches. Some phosgene was left in cup formed by bursting projectile. This boiled away in 8 minutes.

d. Toxicological Data:

First Trench			
Animal:	Position	Symptoms	Result
Goat	60 ft. left of center	Lachrymation, slight depression	Light casualty
"	40 " " " "	Lachrymation	Light casualty
"	20 " " " "	Lachrymation and nasal discharge	Light casualty
"	Center	Normal	No effects
"	20 ft. right of center	Lachrymation, nasal discharge, retching	
"	40 " " " "	Normal	No effects
"	60 " " " "	Lachrymation	Light casualty
"	" " " " "	Slight depression,	
Dog	50 " left " "	Lachrymation	Light casualty
"	50 " right " "	Lachrymation, Depression	Light casualty

Second Trench			
Animal:	Position	Symptoms	Result
Goat	120 ft. left of center	Lachrymation	Light casualty
"	80 " " " "	"	" "
"	60 " " " "	"	" "
"	30 " " " "	Normal	" "
"	Center	Lachrymation, nasal discharge, depression	Light casualty
"	30 ft. right of center	Normal	Unaffected
"	60 " " " "	Nasal discharge	Light casualty
"	" " " " "	Lachrymation,	
"	80 " " " "	Depression	" "
"	120 " " " "	Lachrymation, Depression	" "
Dog	105 " left " "	Lachrymation	" "
"	105 " right " "	Nasal discharge, coughing, vomiting, conjunctivitis	Dead in eleven days



c. Field Results.

Samples were taken as follows:

(a) First trench.

C - center  
D - 20 feet right of center  
E - 60 " " " "  
A - 60 " left " "  
B - 20 " " " "

(b) Second trench.

H - 20 feet left of center  
G - 60 " " " "  
F - 60 " " " "  
I - 20 " right " "  
J - 50 " " " "  
K - 80 " " " "

Sample : Concentrations in Mg./l. for the following intervals of time.

	5 Sec- : onds	10 Sec- : onds	20 sec- : onds	1 Min- : uts	2 Min- : uts	4 Min- : uts
A	0.24	0.12	1.61	5.17	0.52	0.10
B	0.62	1.71	3.91	0.75	0.10	0.24
C	0.10	0.64	2.36	0.53	0.21	0.24
D	0.12	0.21	0.43	0.25	0.24	0.12
E	0.11	0.17	0.42	0.12	0.05	0.05
F	0.17	0.40	1.39	0.65	0.32	0.21
G	-	0.11	2.33	0.25	0.11	0.05
H	0.55	0.23	1.67	0.05	0.16	0.29
I	0.21	0.32	0.53	0.64	0.75	0.99
J	0.10	0.43	0.19	0.13	0.25	0.50
K	0.06	0.20	0.18	0.06	0.53	0.18

**f. Conclusions:**

1. A low concentration of phosgene was produced along 120 ft. in first trench and 240 ft. in second trench.

2. The concentration produced by a Livens drum filled with phosgene fired outside of the trench under the existing weather conditions was too low to produce severe or total casualties to any extent.

3. The low concentration of phosgene in the trenches was probably due to ascending air currents and to a heavy bogster, as most of the gas ascended and passed over the trench.

4. A higher concentration of gas could probably be produced by firing earlier in the morning before the usual increase in ground temperature.

5. Cloud too widely scattered.

6. Persistency:

10 minutes after firing - odor of phosgene pronounced in both trenches.

15 minutes after firing - odor of phosgene practically gone from trenches.

30 minutes after firing - impossible to detect phosgene.

2. Kuhn, Richters, Burrell, Clayton & Oglesby.  
P.T. VIII-4385. R.M. XII-64.

a. Object: To find concentration, variation in concentration, limits and lethal area of cloud of phosgene.

b. Methods:

1. Time - 7.48 A.M. October 17, 1918.
2. Projectile - Livens - 11,880 cc. (36.6 lbs.)  
phosgene - 98.1% pure, placed inside 2nd trench in the old trench system.
3. Booster screwed in with litharge - glycerine cement. 6 oz. black powder used and a squib with paper peeled back.  
Booster grooved 1/8" long, 3/8" wide, machined to full length.
4. Animals - 5 dogs, 20 foot intervals on each side of projectile. Exposure 30 minutes.
5. Samples - 8 groups of 7 samples each taken over 5 minute periods, 4 on each side of projectile at 20, 40, 60 and 100 feet designated left to right A-H.

c. Metecorological Data:

Weather - clear.

Wind velocity at firing, 3-1/5 miles per hour.  
First 5 minutes equals 3.2 miles per hour.

Temperature of air - inside trench	45°E.
" " " - outside "	43°F
" " ground - inside "	48.20°F.
" " " -outside "	46.40°F.

Relative Humidity - inside trench	93%
" " -outside "	92%

Barometer - 29.95 inches.

d. Toxicological Data:

Animal	Position	Result
Dog	100 ft. to left	Died in 8 hours
"	80 " " "	" " 4 "
"	60 " " "	" during exposure
"	40 " " "	" " "
"	20 " " "	" " "
"	20 " " right	" " "
"	40 " " "	" in 30 minutes
"	60 " " "	" " 4 hours
"	80 " " "	Recovered in 10 days
"	120 " " "	" " 5 "

e. Field Results:

Gas Concentrations							
Sample	Concentrations in mg./l. for the following time intervals.						
	5 Sec- onds	10 sec- onds	20 sec- onds	1 Min- ute	2 Min- utes	3 Min- utes	5 Min- utes
A	.00	.00	.05	---	.03	.23	.00
B	.01	.03	1.49	.93	.09	.94	---
C	.44	1.73	8.00	4.40	---	---	1.15
D	45.70	58.90	.02	.20	7.80	4.85	5.72
E	1.90	11.10	1.88	8.50	5.15	4.85	5.90
F	.60	.10	.68	.72	.15	.06	---
G	.08	.02	3.59	3.14	2.74	2.29	1.05
H	.03	.01	.03	.02	.02	.08	.22

f. Conclusions and Remarks:

1. The lethal area for dogs extended 100 ft. to the left and 60 ft. to the right of the projectile.

2. Line of animals should extend farther to get the true limits of the toxic area. Possible toxic concentration beyond the point 100 ft. to left of projectile.

3. Much higher concentration of phosgene at level of dogs than at level of sample bottle (2-1/2 feet from ground).

4. Extent of visible cloud:

5 minutes after firing - 18 inches from ground, 100 feet left, 70 feet right.

10 minutes after firing - 100 feet in length.

30 minutes after firing - 45 feet in length.

5. Persistency:

35 minutes after firing - trench not habitable with masks.

1 hour after firing - no discomfort except within 20 feet of crater.

2 1/2 hours after firing - complete disappearance of odor over crater.

3. O.W.O. #50.

Report of the Chemical Advisory Committee - March 27th -  
April 2, 1917.

a. Object: To determine the suitable bursting charge and to obtain an indication of the nature of the concentration produced by the explosion of a canister filled with phosgene, in a trench.

b. Method: 1 Livens bomb filled with phosgene with a bursting charge of 40 gm. of tetryl was exploded in trench and 32 samples of air taken.

c. Metorological Data:

Wind velocity - 12 miles per hour.

d. Toxicological Results:

Animals used - 22 (goats, rabbits and rats)  
killed by gas - 15 (68%). All dead within 24 hours, many died very soon after exposure.

Casualties in clearly marked zones in trench.  
All animals in zone 17.5 ft. on one side and 41 ft. on the other side of bomb were killed. Partial casualties 37 ft. on one side and 67 ft. on other side.

Criticism: Time of day and amount of phosgene used are omitted. R.E.M.

e. Field Results: Highest concentration 1 volume phosgene in 42 volumes of air, 107 mg./l., collected 20 seconds after explosion, 3 feet from bomb, 1'6" above floor.

At the bursting of the bomb very large quantities of phosgene were thrown into the air far above the ground level; despite this, high concentrations were recorded at first though a sharp drop took place about 1-1/2 minutes after the explosion.

4. C.V. & #37.

Report of C.A.C. August 7 - 13, 1917.

Experiment I.

a. Method:

Four 50 pounder C.I. shell in line at 10 yards to windward of trench, exploded simultaneously, with 16 gm. tetryl bursters and #18 electric fuses.

b. Metacological Data: Wind velocity - 5-3/4 miles per hour.

c. Field Results:

<u>Position</u>	<u>Time</u>	<u>Highest Concentration</u>
On parapet	5 seconds after explosion.	1 volume phosgene to 167 of air = 27.11 mg./l.
In trench at 3'6" above floor	15 seconds after bursting of shell.	1 volume phosgene to 461 of air = 2.41 mg./l.
In dugout		Very low

d. Toxicological Data: Observer wearing small box respirator with extension remained in trench in direct line of the cloud. No odor or taste of phosgene was detected.

Experiment II.

a. Method: One shell exploded as above.

b. Metacological Data: Wind velocity 4 miles per hour.

c. Field Results: Twenty-nine samples taken.

<u>Position</u>	<u>Time</u>	<u>Concentration</u>
In trench 3 ft. from shell 1'8" above floor	10 seconds after explosion of shell	One volume of phosgene to 101 vol. of air - 44.6 mg./l.
In dugout 1'8" above floor.	1-1/4 minutes after explosion of shell	One volume of phosgene in 539 vol. of air - 8.4 mg./l.

Comparison of concentrations obtained by bursting statically various types of missiles filled with phosgene.

Volumes of air containing 1 volume of phosgene - mg./l.								
Position:	(a)	(b)	(c)	(d)				
	Vol. Air	mg./l.	Vol. Air	mg./l.	Vol. Air	mg./l.	Vol. Air	mg./l.
Parasut	167	25.445	154	23.675	188	23.482	217	20.85
Trench	481	9.181	237	18.633	158	27.949	242	17.735
Dugout	56600	0.078	237	18.633	5140	0.659	23800	0.186

- (a) 4 - 60 pr. C.I. shell exploded near a trench (See above).  
 (b) 4 - 4" Stokes bombs " " " " (C.W.C. Report 46, pg. 6.)  
 (c) 3 - 2" T.M. bombs " " " " ( " " 55, " 5.)  
 (d) 10 - 4.5" C.I. Howitzer shell, Mk. I exploded near a trench  
 (C.W.C. Report 66, pg. 9).

Comparison of highest concentrations of phosgene obtained by bursting one missile in trench.

Position:	(a)	(b)	(c)	(d)				
	Vol. Air	mg./l.	Vol. Air	mg./l.	Vol. Air	mg./l.	Vol. Air	mg./l.
Trench	101	45.723	125	35.538	45	96.0	45	105.14
Dug-out	539	8.125	---	---	67	65.91	---	---

- (a) 1 - 60 pr. C.I. shell (see above).  
 (b) 1 - 4" C.I. Stokes bomb (C.W.C. Report 46, pg. 6).  
 (c) 1 - 2" T.M. bomb (Report 53, pg. 3).  
 (d) 1 - Livens drwa (Report 50, pg. 8).

#### d. Toxicological Data

Observer wearing a special box respirator with extension, entered trench immediately after explosion and remained in densest part of cloud for 5 minutes with perfect protection against the phosgene.

#### e. Conclusions

Phosgene is a suitable filling for C.I. shell.



5. G.O.P. 228 (C.W.C. 89).

Report on the front covered by the 6" (25 cwt.) Howitzer when firing shell filled with phosgene.

Time: January 12, 1918.

a. Method.

No. of experiment - 7  
No. howitzers used - 1; No. rounds fired - 22.  
Map range @ 4000 yards; Rate of fire B.F. - 30 seconds.  
Time taken to fire all rounds - 11 minutes.  
Howitzer on center line of section artillery trench -  
Animals over front of 60 yards.  
Shell - 6" (25 cwt.) howitzer, cast iron  
Filling - phosgene  
Bursting chg. - Fumyl C (b)  
Propellant " - 2nd M.C.T.  
Blind Shell - 0

b. Meteorological Data.

Barometer - 29.85 inches  
Thermometer - Wet bulb 87° F.  
Dry " 58° F.  
Ground temperature - 35° F.  
Wind - West, Southwest varying to West and Southwest.  
Wind Velocity - 7 - 4 miles per hour  
Sky - cloudy  
Rainfall - nil during experiment - trace during previous  
24 hours.  
Time of day - 3:15 P.M.

c. Field Results.

Concentrations were determined at various positions at heights of 1 ft. 8 in. and 4 ft. above the ground. Complete tables with diagrams are given in the original report.

Position No. See diagram in original report	Time after burst of first shell when sample was taken.		Height above floor of trench at which sample was taken.		CONCENTRATION	
	Minutes	Seconds	Ft.	Inches	Mg./per liter	Volume of air contained 1 volume of phosgene both at N.T.P.
1	2	45	4	0	nil	nil
6	"	"	"	"	0.49	9240
12	"	"	"	"	0.23	19700
17	"	"	"	"	0.74	6120
18	"	"	1	8	0.23	19700
23	"	"	4	0	2.94	1540
25	"	"	1	8	2.69	1680
28	"	"	4	0	0.13	30200
29	"	"	1	8	0.08	56600
34	"	"	4	0	0.03	56600
39	"	"	"	"	nil	nil
4	5	45	1	8	0.71	6380
5	"	"	4	0	0.87	5200
10	"	"	"	"	0.84	8380
11	"	"	1	8	0.75	6040
15	"	"	4	0	0.13	34800
21	"	"	"	"	0.20	22600
27	"	"	"	"	0.08	56600
33	"	"	"	"	trace	trace
35	"	"	1	8	0.12	37700
38	"	"	4	0"	0.12	37700
39	"	"	1	8	nil	nil
42	"	"	4	0	trace	trace
3	10	15	1	3	0.20	22600
5	"	"	4	0	0.41	11000
8	"	"	"	"	3.25	1390
14	"	"	"	"	0.25	17400
15	"	"	1	3	0.32	14200
20	"	"	4	0	nil	nil
23	"	"	"	"	0.12	37700
30	"	"	"	"	trace	trace
34	"	"	1	8	0.03	56600
37	"	"	4	0	nil	nil
41	"	"	"	"	trace	trace
41	"	"	1	8	0.08	56600
2	11	20	4	0	0.16	23300
7	"	"	"	"	0.20	22600
9	"	"	1	8	7.59	697
13	"	"	4	0	7.04	643
18	"	"	"	"	trace	trace
19	"	"	1	8	0.12	37700
22	"	"	"	"	0.12	37700
24	"	"	4	0	0.30	15100

Position No. See diagram in original report	Time after burst of first shell when sample was taken		Height above floor of trench at which sample was taken		CONCENTRATION Mg./liter	Volume of air containing 1 volume of phos- gene both at N.T.P.
	Min.	Sec.	Ft.	Inches		
31	11	20	4	0	0.35	12900
32	"	"	1	8	0.09	50300
33	"	"	4	0	Trace	trace
40	"	"	"	"	0.20	22600
43	"	"	(Dugouts )		2.55	1600
44	"	"	( at )		0.08	55600
45	"	"	(1ft. 3 in.)		nil	nil

d. Toxicological Results:

(See report for diagram of arrangement of animals.)

Animals	NUMBER USED			Number killed	Remarks
	In trench	In dugout	In open at 22 yds.		
Goats	9	1	0	5	Only those on ex- treme right of trench survived.
Rats	18	0	12*	19	Only those on ex- treme right of trench and on ex- treme flanks in open survived.

\*Excluding 4 rats which escaped during shoot.

e. Conclusions:

1. In the open at 48 yards from the mean point of impact, the front covered by the gun was 35 yards, i.e. from rat 23 to rat 33.

2. In the trench - at 35 yards from the mean point of impact, the front covered was at least 35 yards. In view of the fact that rat 34 was outside the northern limit of the lethal cloud it is probable that the cloud in the trench did not extend beyond goat 18.

3. Front covered by 5" howitzer - 40 yards.

6. Kuhn, Richter, Loevenhart, Kolls, Burrell, Bruce & Smith.  
B.M. XXVII-48 - B.M. XXVIII-90 - (B.K. XXIX-75).  
Smoke Screens.

Time - September 12, 1918, 2:35 P.M.

a. Object: To determine efficiency by field tests of centrifugal nozzle of mobile gas unit, in spraying phosgene.

b. Metereological Conditions:

Cloudy with intermittent sunshine  
Wind - 6 miles per hour  
Air temperature - 63°F.  
Ground " - 67°F.  
Atmospheric pres. - 29.9 in.  
Relative humidity - 45%

c. Methods:

Discharge of Gas:

Amount discharged from cylinder I : 80 lbs.  
" " " " II : 80 "  
Time of discharge of " I : 2 minutes (slow rate)  
" " " " II : 28 seconds (full rate)  
Pressure at nozzle - 200 - 250 lbs.

Arrangement of Animals: (Exposure 30 min.)

1. First row - 40 ft. from cylinder - 5 dogs, 20 ft. intervals
2. Second " - 100 " " " - 7 dogs, 20 ft. intervals
3. Third " - 200 " " " - 6 dogs, 50 ft. intervals

Arrangement of Sampling Bottles (in same rows as animals)

1. First row - 8 bottles: (a) 20 ft. right center; (b) center; (c) 20 ft. left center.
2. Second row - 4 bottles: (d) 40 ft. right center; (e) 20 ft. right center; (f) 20 ft. left center; (g) 40 ft. left center.
3. Third row - 4 bottles: One behind each dog (except two on outer edges) - right to left (H, I, J, K).

d. Field Results:

Sample: Concentration in mg./l. for the following time intervals					
	4 Sec-	10 Sec-	20 Sec-	1 Min-	2 Min-
	conds	conds	conds	mins	mins
A	0.20	11.9	0.25	Mask broke	0.00
B	Vaseline: Mask in stop- broke cock	Mask broke	Mask broke	1.28	0.50
C	Suction	0.00	4.57	0.57	1.88
D	0.00	0.00	0.10	0.20	Lost in lab.
E	0.00	0.00	8.51	2.51	0.00
F	Missing Stopped	0.00	0.00	3.51	0.37
G	no	0.00	0.00	0.20	0.25
H	Poor	Poor	0.00	0.25	0.00
I	Vacuum	0.00	0.00	2.58	0.00
J	0.00	0.00	0.00	0.00	0.00
K	0.00	Vacuum	0.00	0.00	Bottle broken in lab.

e. Toxicological Results:

First Row	P O S I T I O N S		
	Left of center	Center	Right of center
40 ft.	Recovered		Died 36 1/2 hours
20 ft.	Died 10 hrs.		Died 52 1/2 "
0 "		Died 3 hrs.	

	P O S I T I O N S		
	Left of Center	Center	Right of Center
<u>Second Row</u>			
60 ft.	Recovered		Recovered
40 "	Died 150 hrs.		Died 14 days
20 "	Died 10 days		Recovered
0 "		Died 14 hrs.	
<u>Third Row</u>			
150 ft.	Recovered		Died 15 days
100 "	Recovered		Recovered
50 "	Recovered		Died 15 days

f. Conclusions:

A lethal concentration of phosgene was obtained over an area extending 100 feet from cylinders along center line, 20 feet to left on 1st line and 40 feet to left on second line of dogs. Phosgene is equally as effective as arsine in the mobile gas unit.

7. Barcroft. O.C.F. 241. (5423)

a. Object: Experiment to determine the under surface persistency of phosgene, after liberation from artillery shell.

Time - December 24, 1917 - 2:30 P.M.

b. Method:

Artillery Details:

Shell - 50 pr. C.I. filled phosgene  
Bursting charge - C (a)  
Fuse - #106  
Map range 2400 yards - rounds fired 16  
Time taken for all rounds - 11 minutes  
Zero time - at burst of last shell

c. Metereological Data:

Weather Records:

Barometer - 29.97 inches  
Thermometer - Wet bulb - 42.5°F.  
Dry bulb - 48°F.  
Ground - 41.5°F.  
Wind - W.N.W.-W. velocity 7 miles per hour  
Sky - Cloudy  
Rainfall - Nil. during exposure - 0.02" during previous 24 hours.

d. Field Results:

Concentration of Phosgene:

Samples air in craters analyzed - no trace of phosgene.

e. Toxicological Results:

Time:	Individual Observations.
3 min.	Faint indications phosgene going towards crater - none on crater area.
4 min.	Not detected on crater by prone observer - faint odor like CO <sub>2</sub> - test paper negative for phosgene.
5 to 8 min.	No odor of phosgene in five craters - earth turned over - odor like CO <sub>2</sub>

f. Conclusions:

Phosgene has no under surface persistency/

- e. Kuhn, Richter, Burrell, Clayton and Oglesby.  
R.M. XXX-66, P.T. VIII-1399.

Firing a Livens projectile loaded with phosgene and pumice.

2. Object: To find concentration limits and persistency of a cloud of phosgene resulting from firing a Livens projectile loaded with phosgene and pumice in a trench.

b. Method:

1. Time - October 26, 1918, 9:20 A.M.
2. Projectile - Mark I Livens - 5/4 full pumice stone 1/4" in diameter, 7,574 cc. phosgene, 10% air space by volume. 85 gms. loosely packed A.L. T.M.T. #13 detonator.
3. Animals - 3 dogs at 20 ft. intervals on each side of projectile. Exposure 30 minutes.
4. Samples - 4 groups of 10 samples on each side of projectile. 20, 40, 60, 100 ft. from projectile - designated left to right A-H.

c. Metamological Data:

Fairly clear.

Wind velocity - 0.6 miles per hour, (average for 5 min.)

Temperature Air: Inside trench - 58°F.  
" " Outside " - 57°F.  
Ground temperature: Inside " - 57.2°F.  
" " Outside " - 57.2°F.

Relative humidity: Inside " - 94%  
" " Outside " - 94%

Barometer - 29.9 inches

d. Field Results

Sam: Gas concentrations in mg. per liter for the following time intervals.

	5 Sec	10 Sec	15 Sec	1 Min	2 Min	3 Min	5 Min	10 Min	15 Min	20 Min
	ons	ons	ons	uts	uts	uts	uts	uts	uts	uts
A	0.08	0.23	---	0.23	0.41	0.30	0.19	0.00	0.00	0.00
B	0.03	0.15	0.04	3.50	0.79	0.09	0.09	0.15	0.03	0.03
C	0.15	0.09	1.73	4.25	3.62	0.03	0.50	0.49	0.03	0.09
D	0.51	2.35	13.88	3.31	5.33	1.70	4.01	7.80	0.09	0.21
E	31.98	14.88	7.44	1.15	---	7.58	0.41	0.61	0.30	0.08
F	0.27	0.00	1.08	1.65	2.13	0.97	0.09	0.19	0.22	0.19
G	0.09	0.09	---	2.77	---	1.53	0.03	0.09	---	---
H	0.10	0.03	0.03	0.00	0.10	0.03	0.03	0.03	0.03	---



e. Toxicological Results:

Position

150-140 feet left of center	-	Unaffected
120 " " " "	-	Light casualty
100 " " " "	-	Died 18 hours
80 " " " "	-	" 4 "
60 " " " "	-	" 7 "
40 " " " "	-	" 4 "
20 " " " "	-	30 minutes
20 " right " "	-	2 1/2 hours
40 " " " "	-	2 1/2 "
60 " " " "	-	17 "
Remainder " " "	-	Unaffected.

f. Conclusions:

1. Projectile not well thrown out of crater - small cloud - 10 feet in air - sticking close to ground.
2. Casualties - 8 deaths over front 150 feet - same as with phosgene alone.
3. Persistency -  
 20 minutes after firing - not detected by man 20 feet right and 60 feet left of crater.  
 30 minutes after firing - not detected by man 5 feet right and 15 feet left of crater.  
 2 hours after firing - no trace detected over crater.
4. Observations exclusive of analytical results do not show any evidence that pumice renders phosgene more persistent.

9. Kuhn, Richter, Barrell, Clayton.  
P.T. VIII - 4368. B.M. XXXII-93.

a. Object: Study of persistency and lethal area of projectile filled with phosgene absorbed in pumice stone.

b. Method:

Livens projectile about 9 l. phosgene (95.8%) fired statically in bottom of trench. A No. 8 detonator and 85 gms. T.H.T. loosely packed, were used in the detonator.

Animals - 8 dogs, 20 feet intervals each side of Livens.

Exposure - 30 minutes.

Time of Firing - November 8, 1918, 8:00 A.M.

c. Metereological Data:

Weather - clear

Temperature of air - 42°F.

Relative Humidity - 96%

Barometric reading - 29.84 inches

Wind velocity - less than 1 mile per hour

d. Field Results:

left to right.

Eight samples were taken at 20 ft. intervals A-H.

Sample Gas Concentrations in Mg. per liter for the following time intervals.											
Sample	5 Sec	10 Sec	30 Sec	1 Min	2 Min	3 Min	5 Min	10 Min	15 Min	20 Min	30 Min
	1 end	1 end	1 end	1 end	1 end	1 end	1 end	1 end	1 end	1 end	1 end
A	0.0	0.12	13.9	11.5	15.9	12.6	0.64	0.38	0.05	0.10	0.00
B	5.1	24.9	0.0	--	16.5	17.75	3.38	0.52	0.86	0.23	0.11
C	23.2	6.16	8.00	1.44	17.0	12.8	6.3	7.0	1.1	0.23	0.11
D	37.0	7.26	--	--	44.2	34.8	14.4	6.63	8.55	26.8	0.17
E	2.68	--	2.70	6.7	24.4	146.4	165.5	30.0	86.0	158.0	0.17
F	0.23	--	--	--	6.7	5.0	21.4	0.82	0.46	0.78	0.11
G	0.11	--	--	--	2.28	1.56	0.55	0.68	0.05	0.06	0.05
H	0.10	--	--	--	2.82	0.58	0.05	0.00	0.11	0.00	0.05

After 5 min. Cloud moved back over trench.

10 " Cloud very thin and just perceptible to sight.

15 " Cloud outside dispersed but heavy mist remained in trench 30 ft. on either side of projectile.

20 " Strong odor of phosgene 200 ft. N.E. of projectile. 150 ft. N.E. of projectile unbearable without masks.

30 " Bearable without masks on right (south) up to the projectile. On left masks were required at 30 ft.

1 Hour No phosgene detectable in or out of trench.

#### f. Toxicological Results

Position	
160 feet right	Light casualty
140 " "	" "
120 " "	Severe "
100 " "	Died 12 hours
80 " "	" 33 "
60 " "	" 2 1/2 "
40 " "	" 2 "
20 " "	" during exposure
20 " left	" " "
40 " "	" 2 1/2 hours
60 " "	" during exposure
80 " "	" 7 hours
100 " "	" 5 "
120 " "	" 7 "
140 " "	Severe casualty
160 " "	" "

Lethal area - 100 feet to right of projectile, 120 feet to left.

Comparison with test of Oct. 26 (with pumice)

Temperature Oct. 26 - 58°F.

Nov. 8 - 42°F., temperature may account for better cloud and larger lethal area.

Lethal area - Oct. 26th with pumice, 160 feet

Nov. 8th without " , 220 " , wind conditions nearly identical.

f. Conclusions

1. Cloud resulting from detonation of the Livens drum filled with phosgene, is denser and produces a larger lethal area, and is as persistent as that in which phosgene was absorbed in pumice.

10. Zahn, Richter, Burrell, Clayton and Oglesby.  
I.M. IXV-60, P.T. VIII-4593.

Test of gas shell filled with phosgene and pumice.

a. Object. To find the concentration limits and persistency of a cloud of phosgene resulting from firing a Livens projectile loaded with phosgene and pumice in a trench.

b. Method.

Time - December 3, 1918, 9:15 A.M.

Projectile - Mark I Livens filled  $\frac{3}{4}$  full with pieces of pumice, size of grain of wheat. This required 6-7/8 lbs. or 8.5 liters pumice - To this were added phosgene 9,217 cc. (29.1 lbs.) 99.05% pure - air space - 10% by volume.

Position - Livens placed outside trench of old trench system.

Booster charge - 85 gms. loosely packed A-1. T.H.T.

Detonator - #8 inserted.

Cloud - Thrown 10 ft. in air; settled well.

Animals - 3 dogs, 20 feet intervals on each side of projectile. (Total 16 dogs).

Samples - 4 groups on each side, 30, 40, 60, 100 foot intervals, left and right over period of 20 minutes.

c. Metacological Data:

Weather - cloudy - cleared up 10 minutes after shock.

Wind velocity - 3 to 4 miles per hour.

Temperature of air - inside trench - 37° F.

" " " outside " - 37° F.

Relative humidity - inside " - 65%

" " " outside " - 65%

Barometer - 29.8 inches

a. Field Results:

Sec. Gas concentrations in mg. per liter for the following time intervals.											
ple :5 Sec:10 Sec:30 Sec:1 Min:2 Min:5 Min:10 min:15 Min:20 Min:30											
: ends : ends : ends : Htes: Htes : Htes : Htes : Htes : Htes : Htes : Htes : Htes											
: : : : : : : : : : : :											
A :	.00:	5.10	:	4.20	:	2.20	:	.87	:	.00:	.46
B :	9.88:	13.10	:	5.70	:	1.50	:	1.80	:	.87:	1.06
C :	7.25:	14.00	:	5.70	:	2.01	:	4.40	:	1.30:	1.72
D :	.07:	4.60	:	---	:	14.20	:	7.95	:	2.02:	1.90
E :	2.20:	4.30	:	6.36	:	---	:	---	:	.00:	.00
F :	.00:	.00	:	.06	:	1.10	:	.06	:	.00:	.00
G :	.00:	.00	:	.06	:	.00	:	.00	:	.00:	.00
H :	.00:	.00	:	---	:	.06	:	.00	:	.00:	.00

e. Toxicological Results:

7 dogs killed over front of 140 feet.

f. Conclusions:

1. Cloud 19 feet in air.
2. Wind shifted to favor left side of set up.
3. Casualties:  
Killed - 7 dogs - 140 feet from, 49 feet left,  
100 feet left of projectile.  
Severe casualties - 8  
Light " - 2
4. Apparently pumice does not increase persistency,  
but causes cloud to spread more smoothly and with less waste of the filled  
actually used.
5. Persistency:  
5 minutes after shot - heavy mist 20 feet right,  
49 feet left of projectile.  
15 minutes after firing - not detected to 10 feet  
right, 50 feet left.  
20 minutes after firing - not detected to 5 feet  
right of crater, 35 feet left of crater.  
30 minutes after firing - slight odor immediately  
over crater.  
45 minutes after firing - practically no odor.

the cloud so high into air.

Pumice prevents booster charge from scattering

11. Richter, Burrell, Clayton.  
B.M. XXI-78.

This report contains a resume and comparison of data given in B.M. XIX-66 and B.M. XXII-93.

Conclusions:

1. Phosgene absorbed in pumice does not appear more persistent than phosgene alone.

2. Lower initial and average concentration obtained with phosgene plus pumice and a toxic cloud of less extent secured.

12. C.C.P. 178. (8528)

Report on firing trials of 6" (26 cwt.) Howitzer east iron shell charged phosphene Jan. 18, 1918.

aim Object: To determine that 18, 6" howitzer shell should fall 50 yds. upwind of every 40 yds. of front of target in order to produce satisfactory lethal effects. One trial 2/3 rds. used, other 1/3 of number of shells laid down in official pamphlet.

b. Method: Artillery Details.

No. of trial	26	27	27	28	29
No. of 6" How. used	2	2	6	6	6
Map range (yards)	4000	4000	4050	4000	4050
Front engaged "	40	40	50	40	40
Effective area	40x50	40x50	50x50	40x50	40x50
Rounds fired (ranges not included)	11	20	38	47	24
Rate of fire (B.F.)	15 sec.	15 sec.	5 sec.	3 sec.	3 sec.
Time to fire all rounds	4 min.	7 min. 20 sec.	2 min. 40 sec.	3 min. 12 sec.	2 min. 5 sec.
Direction of fire	enfilade	enfilade	frontal	frontal	enfilade
Accuracy of shooting	good	good	good	good	excellent
Diagrams of arrangement of animals, trenches and fall of shells are given in report.					



c. Metacological Data:

No. of trial	26	27	28	29	30
Date	June 19, 1918	June 19, 1918	Oct. 1, 1918	Oct. 13, 1918	Oct. 16, 1918
Time of day	8:40 P.M.	9:30 P.M.	5:45 P.M.	4:40 P.M.	5:00 P.M.
Barometer (inches)	29.50	29.50	29.90	29.78	29.47
Thermometer (dry) of	59.	57.	44.	47.	48.
(wet) of	55.	54.	42.	44.	45.
Ground of	55.	54.	54.	48	44.
Wind direction	SW-N.W	SW-W, NW	W (steady)	W-W, SW	W. NW-W
Wind velocity (m.p.h)	3	4	5	4	5
Rainfall, during experiment	nil	nil	nil	nil	nil
Rainfall during previous 24 hours	0.18"	0.18"	nil	trace	trace
Sky	overcast	overcast	blue- cloudy	blue	overcast
General conditions	dull	dull	fine	fine	dull and threaten- ing, no sunshine.

d. Field Results:

Posn. Section diagram	Time after explosion of first shell		Trial No. 26		Concentrations	
	Mig.	Sec.	Height above floor of trench ft. in.	Mg./liter Phosgene	Volume of air con- taining 1 vol. phos- gene both at N.T.P.	Liquid fill- ing phosgene in cc. per cubic meter of sample.
25	zero		4 0	6.89	700	4.811
26	"		4 0	5.27	900	3.681
28	"		1 8	6.79	700	4.742
1	2	0	4 0	trace	trace	---
6	2	0	4 0	trace	trace	---
9	2	0	1 8	6.24	700	4.358
12	2	0	4 0	1.02	4400	0.712
15	2	0	4 0	0.12	40000	0.084

Post- Section diagram	Time after explosion of first shell		Height above floor of trench		Mg./liter Phosgene	Concentrations	
	Min.	Sec.	ft.	in.		Volume of air con- taining 1 vol. phos- gene both at N.T.P.	Liquid fill- ing phosgene in ccs. per cubic meter of sample
18	2	0	4	0	1.75	2600	1.222
21	"	"	"	"	25.71	170	13.65
23	"	"	"	"	9.59	6000	0.412
3	3	30	"	"	0.08	60000	0.056
6	"	"	"	"	nil	---	---
7	"	"	"	"	trace	trace	---
12	"	"	1	8	0.65	7000	0.454
14	"	"	4	0	0.78	6000	0.545
24	"	"	1	8	11.65	390	8.127
2	4	0	"	0	trace	trace	---
6	"	"	1	8	"	"	---
8	"	"	4	0	"	"	---
11	"	"	"	"	0.80	6000	0.559
14	"	"	1	8	0.68	7000	0.475
17	"	"	4	0	0.91	5000	0.635
20	"	"	1	8	0.37	12000	0.253
2	4	30	1	8	0.09	50000	0.063
4	"	"	4	0	0.09	50000	0.063
10	"	"	"	"	trace	trace	---
13	"	"	"	"	0.31	15000	0.217
16	"	"	1	8	0.08	60000	0.056
16	"	"	"	"	0.19	25000	0.133
19	"	"	4	0	0.17	25000	0.119
22	"	"	1	8	0.76	6000	0.531
24	"	"	4	0	8.54	500	5.965
2700	"	"	1	8	trace	trace	---
2800	"	"	1	8	nil	nil	---
2900	"	"	1	8	"	"	---

Trial 25 To ascertain travel of phosgene cloud

Distance from	Mg./liter Phosgene	Volume of air containing 1 vol. phosgene both at N.T.P.	Remarks
500 yards	0.04	10000	Without AgNO <sub>3</sub> guard tube
	0.04	"	With " " "
500 yards	0.04	10000	Without " " "
	0.04	"	With " " "
1000 yards	nil	trace	Without " " "
	nil	"	With " " "
1000 yards	nil	trace	Without " " "
	nil	"	With " " "

(2) Trial #27					Concentration Phosgene		
Posm. No.	Time after explosion or first shell	Height above floor of trench	Mg./liter Phosgene	Volume of air containing 1 vol. phosgene both at N.T.P.	Liquid filling phosgene in eos. per cubic meter of sample		
Diagram	Min.	Sec.	Ft.	In.			
1	1	40	4	0	1.55	5400	0.929
5	"	"	1	8	0.65	7000	0.454
7	"	"	4	0	0.75	6000	0.510
11	"	"	1	8	1.24	5700	0.866
13	"	"	4	0	0.52	9000	0.363
16	"	"	4	0	0.32	14000	0.224
19	"	"	4	0	0.76	6000	0.531
24	"	"	4	0	0.61	7000	0.426
27	"	"	1	8	trace	trace	---
3	3	50	4	0	nil	nil	---
6	"	"	4	0	1.01	4600	0.705
9	"	"	4	0	nil	nil	---
10	"	"	"	"	nil	nil	---
13	"	"	1	8	trace	trace	---
15	"	"	4	0	"	"	---
21	"	"	"	"	0.19	25000	0.126
22	"	"	"	"	0.49	9000	0.342
27	"	"	"	"	0.14	3000	0.098
2	5	0	"	"	2.02	2200	1.411
8	"	"	1	8	0.57	8000	0.398
9	"	"	4	0	1.05	4500	0.733
12	"	"	"	"	0.36	13000	0.251
15	"	"	1	8	trace	trace	---
18	"	"	4	0	0.13	35000	0.091
21	"	"	1	8	0.13	35000	0.091
23	"	"	4	0	0.16	25000	0.126
26	"	"	"	"	trace	trace	---
4	7	20	"	"	0.09	50000	0.063
11	"	"	"	"	nil	nil	---
14	"	"	"	"	0.14	30000	0.098
17	"	"	1	8	0.18	25000	0.126
20	"	"	4	0	trace	trace	---
23	"	"	1	8	0.16	30000	0.112
25	"	"	4	0	0.08	60000	0.058
38 D.O.	"	"	1	8	nil	nil	---
39 D.O.	"	"	"	"	trace	trace	---
30 D.O.	"	"	"	"	nil	nil	---

# General Average Concentrations

Trial 26					Trial 27				
General Average Concentrations					General Average Concentration				
Samples and Volume of air: Mg./l.	Shell	Time	Volume of air: Mg./l.	Shell	Time	Volume of air: Mg./l.	Shell	Time	
Sample Nos. per volume of:	Burst: of		per volume of:	Burst: of		per volume of:	Burst: of		
phosgene			phosgene			phosgene			
1 (1-4)	90,000	0.049	nil	---	5,000	0.883	nil	---	
2 (4-9)	4,200	1.051	nil	---	6,500	0.679	nil	---	
3 (10-19)	8,000	0.552	nil	4 min.	16,000	0.276	nil	7 min.	
				0 sec.				20 sec.	
4 (20-26)	900	4.906			250,000	0.166	nil		
One of 170** - 25.976 mg./l not included in general average concentration									

\*\*Since the later higher figures were subsequently maintained, they are included in the general average concentration.

Direct hit in trial 26 caused high local concentration and great mortality. When higher number, low calibre shell (4.5 inches) are replaced by smaller number of high calibre shell (6 inches, the variability of concentration is greatly increased.

(3) Trial 27			Concentrations Phosgene	
Posn. No. on Diagram	Time after explosion of first shell	Mg./liter phosgene	Volume of air containing 1 vol. phosgene both at M.T.P.	Liquid filling phosgene in ccs. per cubic meter of sample.
	Min.			
5	1	0.26	17000	0.182
6	"	0.13	35000	0.091
11	"	0.14	30000	0.098
13	"	0.95	4800	0.683
19	"	0.09	60000	0.063
1	1-2	0.53	9000	0.370
4	1-2	0.18	25000	0.126
7	1-2	0.41	11000	0.286
9	1-2	1.40	5500	0.978
12	1-2	0.08	60000	0.066
14	1-2	nil	nil	---
16	1-2	trace	trace	---
18	1-2	0.15	35000	0.091
2	3	0.12	40000	0.084
5	"	0.39	12000	0.272
8	"	0.14	30000	0.398
10	"	trace	trace	---
15	"	0.22	20000	0.154
17	"	0.09	50000	0.063

\* Time only approximate.

## (4) Trial 500

Position No. see diagram in origi- nal report	Time after explosion of first shell		Height above floor of trench		Hg./Liter Phosgene	Volume of air containing 1 vol phosgene both at N.T.P.	Liquid filling in cc. per cubic meter of sample.
	Min.	Sec.	Ft.	In.			
3	1	55*	8	0	19.53	230	13.640
12	"	55	"	"	0.96	4700	0.671
14	"	"	1	8	0.46	9800	0.521
17	"	"	4.0	0	0.77	6000	0.538
22	"	"	1	8	0.98	4600	0.684
28	"	"	4	0	0.47	10000	0.528
2	2	45*	1	8	125.10	36	87.560
5	"	45*	4	0	12.74	360	8.898
8	"	45*	"	"	6.05	700	4.226
11	"	45	1	8	0.47	7600	0.528
14	"	"	4	0	0.52	8700	0.563
16	"	45	4	0	2.36	1900	1.648
19	"	"	4	0	14.43	610	10.080
21	"	"	4	0	10.80	420	7.543
24	"	"	"	"	1.27	3600	0.887
1	6	0*	"	"	23.14	200	16.160
10	"	"	"	"	0.09	50000	0.063
13	"	"	"	"	0.12	40000	0.084
15	"	"	"	"	trace	trace	--
18	"	"	"	"	0.09	40000	0.063
20	"	"	1	8	0.30	15000	0.210
23	"	"	4	0	1.96	2300	1.369
27	"	"	1	8	0.20	25000	0.140
Do 29	"	0	1	8	0.32	14000	0.224
Do 30	"	"	"	"	1.19	3800	0.831
4	Unknown	"	1	8	6.30	700	4.399
6	"	"	4	0	22.72	200	15.870
7	"	"	"	"	47.19	96	32.960
9	"	"	"	"	5.63	800	3.931
25	"	"	1	8	0.49	9200	0.342

\*These times are uncertain, owing to shell bursts in the trench in this neighborhood.

Table to show influence of direct hits on the concentration.

Section of trench	Times at which samples were opened				Remarks
(Nos. of sample)	11 Min. : 55 Sec.	12 Min. : 45 Sec.	15 Min. : 10 Sec.	Unknown : opened by	
Position				shell splinter and shock	3 direct hits.
(in brackets)	g. : kg./l. *	kg./l. *	kg./l. *	kg./l. *	
1 (1-7)	1230 : 19.2 : 122.66	200 : 22.08	700 : 6.2		
2 (8-12)	14700 : 0.8835	700 : 16.308	50000 : 0.0883	600 : 5.52	
3 (13-1)	19800 : 0.4506	18700 : 0.5076	14000 : 0.1104		
	16000 : 0.735	1900 : 2.324	trace		1 hit close to trench
		310 : 14.245	50000 : 0.0883		
		420 : 10.514	15000 : 0.2944		
4 (22-28)	14600 : 0.96	3600 : 1.226	2300 : 1.72	9200 : 0.48	
	2000 : 0.4416		125000 : 0.175		

\* Volume of air per volume phosgene.

C.C.P. 178.

(5) Trial #39.

Position No. See diagram in original report	Time after explosion of first shell	Height above ground	kg./liter phosgene	Volume of air containing 1 volume of phosgene both at N.T.P.	Liquid filling phosgene in ccs. per cubic meter of sample
Min.	Sec.				
7	16	ground	trace	trace	---
9	15	level	3.42	1500	2.389
12	59	"	0.21	20000	0.147
4	50	"	trace	trace	---
8	1	7	0.21	20000	0.147
10	1	21	0.16	30000	0.112
1	2	20	0.09	50000	0.063
2	"	"	0.09	50000	0.063
3	"	"	0.09	50000	0.063
5	"	"	trace	trace	---
11	"	"	0.09	50000	0.063
13	"	"	0.08	60000	0.056
14	"	"	trace	trace	---
15	"	"	trace	trace	---
6	taken by ranger		0.29	15000	0.203

e. Toxicological Data:

Position	No. goats used			Dead in 48 hours			CASUALTIES						PERCENTAGES					
							Severe, Class A and B			Light, Class C.			Dead			Severe included		
(No. of trial)	26	27	38	26	27	38	26	27	38	26	27	38	26	27	38	26	27	38
Trench	7	7	7	2	-	4	3	-	1	2	5	2	28	0	57	71	0	81
Dugout	1	1	2	1	-	0	-	-	1	-	1	1	100	0	0	100	0	50
Open at 50 yards	5	4	-	0	-	-	1	-	-	3	2	-	0	0	-	20	0	-
Open at 75 yards	4	3	-	-	-	-	-	-	-	3	2	-	0	0	-	0	0	-
Open at 100 yards	3	3	-	-	-	-	-	-	-	1	3	-	0	0	-	0	0	-
	No. rats used			Killed			Gassed			Normal			PERCENTAGES					
													Killed			Killed and Gassed		
Trench	5	7	8	5	4	8	-	1	-	-	2	-	100	57	100	100	71	100
Dugout	1	1	2	1	1	1	-	-	1	-	-	1	100	100	50	100	100	50
Open at 50 yards	4	4	-	1	2	-	1	1	-	2	1	-	25	50	-	50	75	-
Open at 100 yards	2	3	-	1	1	-	1	2	-	-	0	-	50	50	-	100	100	-
	No. guinea pigs used			Killed			Gassed			Normal			PERCENTAGES					
													Killed			Killed and Gassed		
Trial No.	37	39		37	39		37	39		37	39		37	39		37	39	
On ground level	36	35		9	3		12	16		15	16		25	9		58	54	
At 4 feet	18	16		7	2		5	4		6	10		39	12		67	37	
Total	54	51		16	5		17	20		21	26		30	10		61	50	

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1. Conclusions:

1. Effects of direct hit in any position where gas may be trapped, e.g., a trench, are very marked. Very high and persistent though very local concentrations of gas are produced.

2. The general average concentration of phosgene is of the order of 1/5000 to 1/10000, (0.883 to 0.4416 mg./l.) not including high local concentrations.

3. The cloud produced may be expected to travel to

50 yards	in a concentration of	1/5000 to 1/10000	(0.883 - 0.4416 mg./l.)
100	" " "	" "	1/30000 (0.1472 mg./l.)
500	" " "	" "	1/100000 (0.04416 mg./l.)

4. The throw forward of liquid spray is about 10 yards.

5. Variations in concentrations greatly increased by replacing a large number of low calibre shell by a small number of high calibre shell.

6. The system of taking samples in the open requires considerable extension and elaboration, before reliable figures can be obtained.



13. C.C.P. 221 (5770).

Report on firing trials of Stokes bomb.

a. Object: To ascertain highest concentration of gas obtainable by firing 40 - 4" Stokes bombs from one mortar in 2 minutes, on 20 yard front.

b. Methods

Artillery details:

Time - November 1, 1917 - 3:30 P.M.

4" C.I. Bombs filled with phosgene.

2

No. Stokes mortar - 1

Bursting charge - Powder chambers head, instantaneous fuse (9 inch) #8 com. detonator.

Propellant charge - 1 biscuit

Fuse #146 Mark I

Range @ 350 yards. Front engaged 20 yards.

Effective area 20x30 yards - Rounds fired - 38

Rounds in effective area 12 - Rate of fire - rapid

Time taken to fire all rounds 1 min. 45 sec. -

Direction of fire - frontal

Ammunition - very bad.

c. Meteorological Data:

Barometer	-	29.66 inches
Thermometer, dry bulb		53.2°F.
wet "		53.0°F.
Ground temperature		52.5°F.
Wind direction		S.
Wind velocity		4-1/2 miles per hour
Sky		Overcast
Rainfall		nil during experiment
		0.03 during previous
		24 hours.

## a. Field Results:

Observations on travel of phosgene vapors.

1500 yards from trenches - phosgene could be detected by colored test paper. (max limit of detection).

Position No. (see diagram in original report)	Time after burst of first bomb when sample was taken.		Height above floor of trench at which sample was taken		Mg./liter	Volume of air containing 1 volume of phos- gene both at N.T.P.
	Min.	Sec.				
* 13			St.	Inches		
4		35	1	8	60.61	75
8		38	4	0	15.75	270
11		"	"	"	5.55	691
15		"	"	"	5.25	862
18		"	"	"	20.57	220
20		"	1	8	5.25	831
24		"	4	0	2.34	1940
28		"	1	8	0.17	26600
1	1	5	4	0	trace	—
5	"	"	"	"	9.45	479
9	"	"	"	"	13.58	251
12	"	"	"	"	12.12	374
14	"	"	"	"	27.35	186
18	"	"	2	8	84.55	54
21	"	"	4	0	45.28	98
25	"	"	"	"	32.58	139
27	"	"	"	"	0.05	56600
1	1	16	1	8	0.20	22600
2	"	"	4	0	7.62	594
3	"	"	1	8	7.57	598
6	"	"	4	0	8.47	534
10	"	"	"	"	9.88	458
12	"	"	"	"	21.23	213
14	"	"	"	"	0.77	5880
17	"	"	"	"	22.82	196
22	"	"	"	"	36.54	68
26	"	"	"	"	19.43	76
3	1	45	Last bomb exploded		0.20	22600
7	"	"	4	0	5.49	825
10	"	"	"	"	9.00	503
12	"	"	"	"	15.62	290
15	"	"	"	"	18.74	232
15	"	"	"	"	25.48	178
			1	8	28.80	157

Position No. (see diagram in original report)	Time after burst of first bomb when sample was taken		Height above floor of trench at which sample was taken.		Kg./liter	Volume of air containing 1 volume of phos- gene both at M.T.P.
	Min.	Sec.	Ft.	Inches		
19	1	45	4	0	23.32	194
22	"	"	1	8	49.22	92
23	"	"	4	0	17.83	254
27	"	"	1	8	42.80	106
32 (In the open)*	"	"	4	0	0.15	34800
	"	"	1	8 (above ground)	1.49	3040
8	5	0	1	8	0.19	23800
15	"	"	"	"	0.08	56600
8	6	0	1	0	0.08	56600
15	"	"	"	"	0.16	28300
8	7	0	"	"	0.52	14200
15	"	"	"	"	0.24	18900
8	8	0	"	"	0.08	56500
15	"	"	"	"	0.24	18900
29) In shelter	1	25	1	8	0.15	28500
31) dugouts	1	45	above floor of dugout		67.14	67
31)	15	0	"		13.55	334
31)	25	0	"		4.39	1031
30) In deep dugouts.	1	45	"		5.58	811

\*The bottle in this position opened by splinters from bomb which fell near it during the ranging.

#### c. Toxicological Data

See diagram in report on arrangement of animals.

Position of goats	No. used	CASUALTIES				Percentages		Remarks
		Dead in 48 hrs.	Severe Class A or B	Light Class C	Dead	Casual- ties in- clude dead		
In trench	9	0	0	1	89	89		
In dugout	1	1	0	0	100	100		Of 7 rats, 6 died
In open, at 50 yards	5	0	2	3	0	40		1 rats which died
In open, at 100 yards	3	0	0	1	0	0		Of 5 rats, 1 died
								Of 3 rats, 1 died.

f. Conclusions:

Maximum concentration 1/54 (94.55 mg./l.)

Seven greater than 1/100 (45.78 mg./l.)

Thirteen greater than 1/200 (22.89 mg./l.)

14. C.C.P. 107. (8451)

Report on firing trial of 4.5" howitzer cast iron shell - filled with phosphene.

a. Object: To determine persistency of phasgers in underground - area shelled with 4.5" howitzers.

b. Methods:

### Artillery Details.

No. of trial - C. G. 32  
No. shells used - 4 - 4.5" howitzer  
"C" No. of shell - 0.644  
Chemical filling - phosgene  
Bursting charge - C.I.C. (a)  
Propellant - 2nd N.C.T.  
Fuse - 106 Ill  
Blind shell - 0  
Map range - 1750  
Target engaged - 40x40 yards  
Rounds fired - (ranges not included) - 50  
Rounds in target - 34  
Rate of fire B.F. - 3 Sec.  
Time to fire for all rounds 5 min. 45 sec.  
Direction of fire - frontal  
Accuracy of shooting - very good.

Two minutes after last shell exploded, 24 rats and 8 guinea pigs were placed in shelled area. Guinea pigs removed in 5 minutes, rats in 62 minutes.

c. Metereological Data:

Time July 31, 1918 - 7:45 P.M.  
Barometer - 29.75 inches  
Thermometer - dry bulb - 68°F.  
                  wet       "   - 60°F.  
Surface temperature - 63°F.  
Wind velocity - 3 miles per hour; direction S.W.-  
                  S.W.S.

Sky - Cloudy  
Rainfall - nil during exposure and previous 24 hours.  
Conditions - fair

### d. Results:

Neither observers nor animals were able to detect the presence of phosgene.

Post mortem examination of animals showed no signs of gassing.  
It is reasonable to assume that phosgene has no persistency in undergrowth.

15. C.O.P. 205. (2082)

Experiments to determine the persistency of lethal gases in dugout - Phosgene.

Previous reports state that shell filled with phosgene exploded in open so that, cloud passes over trench containing dugout, little gas is collected in dugout.

When shell were exploded in trench, high concentrations of phosgene are found in dugout.

Description of Dugouts:

Two dugouts communicating with trench by shafts 17 feet apart; total capacity of each dugout (including shaft) 1270 cubic feet; floor 15 feet 6 inches below level of bottom of trench; floor 21 feet 6 inches below general ground level.

EXPERIMENT I: 2" T.M. Bombs filled with phosgene.

Time of trial - September 10, 1917 - 7:00 P.M.

a. Method:

Artillery Details:

3 T.M. bombs filled with phosgene, fitted with 16 commercial electrical detonators, arranged near trench as shown in sketch in original report.

Time of bursting - 5 seconds interval between #1 and 2) commencing with bomb nearest trench. Ten seconds between #2 and 3. Dugout entrances faced down wind.

b. Metastorological Data:

Barometer	-	29.90 inches
Thermometer - Wet bulb	-	60°F.
Dry "	-	61.5 °F.
Ground	-	56.5 °F.
Wind Direction	-	S.E.
" Velocity	-	2½ miles per hour
Sky	-	Blue, cloudy
Rainfall	-	Nil during experiment, 0.02 inches during previous twenty-four hours.

c. Field Results:

Position (see sketch in original report)	Time after explosion of first shell		Height above floor of trench or dugout at which sample was taken		CONCENTRATIONS	
	Min.	Sec.	Ft.	Inches	Mg./liter	Volume air containing one volume phosgene both at N.T.P.
B (dugout)		40	1	8	0.08	56600
		55	"	"	Nil	-
	1	10	"	"	trace	-
	1	25	"	"	"	-
	1	40	"	"	Nil	-
	1	55	"	"	"	-
	2	10	"	"	"	-
	2	25	"	"	"	-
C (dugout)		40	4	0	Nil	-
		55	"	"	"	-
	1	10	"	"	"	-
	1	25	"	"	"	-
	1	40	"	"	"	-
	1	55	"	"	"	-
	2	10	"	"	"	-
	2	25	"	"	"	-
A (trench)		30	1	8	18.56	244
		35	"	"	18.49	245
		40	"	"	14.10	321
		45	"	"	13.73	330
		50	"	"	12.80	353
		55	"	"	8.70	529
	1	0	"	"	3.24	1400
	1	5	"	"	4.46	1020

Little or no phosgene from bombs burst in open, sinks into deep dugout, although the cloud of phosgene passing over the trench gives rise to high concentrations in trench midway between the shafts.

d. Observations on Distance Travelled by Cloud.

1550 yards distance - unpleasant odor, strong tobacco reaction lasting several hours - no lachrymation - no respirator needed.



EXPERIMENT NO. II: 2" T.M. Bombs Filled with Phosgene in the Trench.

Time of trial - September 11, 1917 - 6:20 P.M.

a. Method:

Artillery Details:

2 bombs on floor of trench midway between 2 shafts of dugout. Time of exploding - 15 seconds intervals by means of #8 electrical detonators. Both bombs well opened, dense cloud filled trench. Wind blowing on to entrances of dugouts. Conditions very favorable to entrance into western shaft.

b. Meteorological Data:

Barometer	-	29.63 inches
Thermometer - wet bulb	-	65°F.
dry "	-	65°F.
In dugout	-	54°F.
Wind Direction	-	North
" Velocity	-	4 miles per hours
Sky	-	Dull
Rainfall	-	Nil during 1st hour - then heavy shower for several minutes - trace during previous twenty-four hours.

c. Field Results:

Samples collected in centre of dugout height -  
1 ft. 6 inches above floor.

Time after explosion of first bomb		CONCENTRATIONS	
Min.	Sec.	Mg. per liter Phosgene	Volume of air containing one volume of phosgene both at N.E.P.
	40	77.23	59
	55	92.12	49
1	10	87.22	52
1	25	83.83	54
1	40	82.10	55
1	55	85.21	53
2	10	84.14	54
2	25	82.54	55
3	25	78.21	58
4	25	72.16	63
5	25	66.77	68
10	0	52.75	86
15	0	29.21	115
20	0	31.72	143
40	0	12.21	371
25	0	26.20	173
25	0	7.09	659
Hrs.	Min.		
1	10	3.48	1350
1	25	1.85	2450
1	55	0.73	6200
2	25	0.64	7070
2	55	0.49	9240
2	25	0.26	17400

d. Observations.

For 3 minutes 25 seconds after burst of bomb concentration in dugout remained at 1/50 to 1/50. In 15 minutes the concentration was 1/100. In one hour 10 minutes the concentration was 1/1000.

Persistence	Observations
15 Seconds	Explosion of last bomb - very dense cloud in trench.
55 "	Maximum concentration phosgene in dugout.
2 minutes	Dense cloud - light from electric torch penetrates for 1 ft.
40 minutes	Cloud in dugout still very dense - concentration phosgene 1 in 371.
55 minutes	Trench still smelt strongly of phosgene.
1 Hr. 10 min.	Still very marked smell of phosgene in trench near western shaft of dugout.

<u>Persistence</u>	<u>Observations</u>
1 hr. 25 min.	Concentration of phosgene in dugout - 1 in 2450. Electric torch penetrates across dugout. Trench practically free from phosgene except occasionally near entrance to the dugout.
2 hrs. 55 min.	Concentration of phosgene in dugout - 1 in 9240. Observer without protection could descend to within 5 steps of bottom of dugout.
3 hrs. 25 min.	Concentration of phosgene - 1 in 17400. Unprotected observer walked through dugout too much phosgene present for him to remain below.
4 hrs. 25 min.	Dugout clear of phosgene.
3 hrs. 55 min.	Only faint odor of phosgene in dugout.

EXPERIMENT NO. 111 4" C.I. Stokes Bomb Filled Phosgene in Trench.

Time of trial - September 28, 1917 - 10:00 A.M.

a. Methods

Artillery Details:

2 Stokes bomb, 2 feet apart at bottom of trench midway between 2 shafts of dugout, exploded 30 seconds intervals. Entrance to dugouts faced directly down wind - samples collected in center of dugout 1 ft. 8 in. above floor.

b. Metacological Data:

Barometer	-	29.99 in.
Thermometer - wet bulb	-	54.4°F.
dry "	-	55.8°F.
ground	-	60°F.
Wind direction	-	Southwest
" velocity	-	7 miles per hour
Rainfall	-	nil during exposure, trace during previous 24 hours

c. Field Results

Time after explosion of first bomb			<u>CONCENTRATIONS</u>	
			<u>Mg. per liter Phosgene</u>	<u>Volume of air containing one volume phosgene both at F.T.P.</u>
Hrs.	Min.	Sec.		
		30	17.38	261
		45	32.86	140
1	0		43.40	104

Time after explosion of first bomb			CONCENTRATIONS	
Hrs.	Mins.	Secs.	Mg. per liter Phosgene	Volume of air containing one volume phosgene both at N.T.P.
	1	15	51.75	87
	1	30	51.52	88
	2	0	50.52	90
	2	30	47.07	96
	3	0	49.11	94
	4	0	44.55	102
	5	0	42.03	108
	10	0	33.09	141
	15	0	22.24	204
	20	0	11.88	331
	50	0	2.84	1500
1	20		0.75	6040
1	50		0.32	14200
3	0		trace	-
4	25		0.05	75500
5	47		trace	-

d. Observations:

Persistence	Observations:
30 Seconds	Last bomb exploded. Pool of liquid phosgene on floor of trench.
1 Min. 30 sec.	Maximum concentration of phosgene (1 in 88) attained in dugout.
2 Min.	No liquid phosgene left on floor of trench.
9 Min.	Trench between entrances of dugout clear of phosgene.
25 Min.	Detected in trench just outside western shaft of dugout. Phosgene still issuing from western shaft. Unprotected observer to within 5 steps bottom eastern shaft - encountered strong concentration of phosgene.
1 hr. 20 min.	Phosgene still fairly strong in dugout and western stairway decreasing.
1 hr. 50 min.	
3 hr.	Test paper slow reaction in dugout - faint odor phosgene still enough to be untenable.
4 hr. 25 min.	Phosgene not detected - acid fumes noticeable.
5 hr. 47 min.	Dugout and stairway clear of visible cloud.

EXPERIMENT NO. IV: 4.5" C.I. Howitzer Shell (Mark V)  
Filled Phosgene in Trench.

Time of Trial - Oct. 5, 1917 - 5:00 P.M.

a. Methods

Artillery Details:

Two howitzer shells - in trench midway between entrance to dugout, exploded separately, interval of 30 seconds between; wind blowing down trench across entrances to dugout.

b. Metacological Data:

Barometer	-	29.75 inches
Thermometer - wet bulb	-	44°F.
dry "	-	46°F.
ground	-	42°F.
Wind direction	-	E.W.-W.N.W.
" velocity	-	11 miles per hour
Sky	-	Blue
Rainfall	-	Nil during exposure - 0.24 inches during previous 24 hours.

c. Field Results:

			<u>Samples collected in center dugout 1 ft. 8 in. above floor.</u>	
			<u>CONCENTRATIONS</u>	
Time after explosion of first shell			Mg./liter phosgene	Volume of air containing one volume of phosgene both at E.T.P.
Hr.	Min.	Sec.		
		30	traces	-
		45	5.51	622
1	0		12.08	375
1	15		17.20	253
1	30		16.36	277
2	0		13.86	327
2	30		13.90	326
3	0		14.48	313
4	0		13.00	348
5	0		9.86	459
10	0		2.84	1590
15	0		0.27	16800
20	0		0.08	56000
30	0		Nil	-
1	20		Nil	-

d. Observations:

<u>Time</u>	<u>Observations</u>
30 Seconds	Explosion of last shell.
1 Min. 15 Sec.	Maximum concentration of phosgene in dugout - 1 in 263.
5 Minutes	Very strong smell of phosgene
15 Minutes	in the trench
28 Minutes	Trench and entrances of dugout clear of phosgene.
50 Minutes	Phosgene could only just be detected in dugout by
	smell and test paper.
1 Hr. 20 Min.	Dugout clear of phosgene - not detected by smell or
	test paper.

General Observations:

1. High concentrations of phosgene in deep dugouts not expected from shell and bombs bursting near the trench. Bursting in trench or on top of parapet may produce high initial concentration.
2. Impossible to state time at which dugout will be clear of gas - depends on weather especially wind velocity and ventilation of dugout.
3. All dugouts used in these experiments unprotected.

16. C.C.P. 216. (5993)

Report on firing trials of 4.5" howitzer C.I. mark X shell filled with phosgene.

a. Method:

Saturday, March 9, 1918, 5:15 P.M.

Artillery Details:

Number of 4.5 howitzer used. 2

Type of shell, C.I. mark X.

Map range, 1750 yards.

Front engaged, 40 yards.

Effective area 40x30 yards.

Rounds fired, 51.

In effective area, 42

Rate of fire, battery fire, 3 seconds with pause.

Time taken to fire all rounds, 6 minutes 10 seconds.

b. Metacological Data:

Barometer - 29.85 inches

thermometer - dry bulb 45°F.

wet " 40°F.

ground. 38°F.

Wind direction - South East.

Wind velocity - 3 to 1 miles per hour.

Sky - blue

Rainfall - nil during exposure, or previous 24 hours.

c. Field Results

Position (see original)	Time after explosion of first shell		Height above floor, trench		Kg./L	Concentrations	
	Min.	Sec.	Ft. in.			1 Part in	Liquid per cubic meter in con.
1	0	45	4	0	0.12	40000	0.085
1	"	"	1	8	0.52	9000	0.363
6	"	"	4	0	1.07	4200	0.747
9	"	"	"	"	1.04	4400	0.726
14	"	"	"	"	nil	-	nil
1717	"	"	1	8	0.08	60000	0.056
18	"	"	4	0	0.16	30000	0.112
23	"	"	1	8	nil	-	nil
24	"	"	4	0	0.08	60000	0.056
5	1	30	"	"	0.19	25000	0.133
6	"	"	1	8	nil	-	nil
8	"	"	"	"	0.55	8000	0.384
13	"	"	4	0	1.14	4000	0.796
15	"	"	1	83	0.43	11000	0.300
17	"	"	4	0	0.71	6000	0.496
19	"	"	"	"	1.90	2400	1.327
22	"	"	"	"	1.91	2100	1.334
2	2	30	"	"	0.08	60000	0.056
11	"	"	"	"	0.42	11000	0.293
12	"	"	1	8	0.39	12000	0.272
14	"	"	4	0	0.16	30000	0.112
21	"	"	"	"	11.27	400	7.868
3	4	35	"	"	0.08	60000	0.056
4	"	"	1	8	0.08	60000	0.056
7	"	"	4	0	0.18	25000	0.126
10	"	"	"	"	0.18	250000	0.126
10	"	"	1	8	0.09	50000	0.063
15	"	"	4	0	1.97	2300	1.376
19	"	"	"	"	trace	-	-
19	"	"	1	8	1.15	44000	0.803
Shelter dugout	"	"	above floor		trace	-	-
Deep dugout, 25	"	"	of the		trace	-	-
20 Opened by shell at	2	0	dugout 1 8		27.51	160	19.220



Inasmuch as goat No. 1 was killed by a plinter and that very high local concentrations of phosgene was recorded at sampling positions 20 and 21, it seems probable that an unobserved shell must have been in this position of the trench towards middle of period during which samples were taken (4 minutes 35 seconds, the trial lasted 6 minutes 10 seconds).

Concentrations in mg./l. of phosgene.

Trench Sector	Sampling Position	Time after commencement of firing	45 Seconds	1 Min. 30 Sec.	2 Min. 30 Sec.	4 Min. 30 Sec.
1	1 - 4		0.1104		0.0736	0.0736
			0.4907			0.0736
			1.0514	0.1766	0.4014	0.1766
2	5 - 11		1.0036	nil		0.1766
				0.552		0.0883
			nil	1.104	0.368	0.192
3	12 - 18		0.0736	0.4014	0.1472	
			0.1472	0.736		
4	19 - 22			1.84		trace
				1.84		11.04*
5	23 - 24		nil			
			0.0736			

\*Local high concentrations probably due to burst of shell in trench.

These figures are not indicated in table-

Trench Sector	Average concentration for total period	Average concentration for whole trench, during total period
1	0.1766	
2	0.4014	
3	0.552	0.6793
4	1.5771	

Accurate prediction of deaths and severe casualties possible from consideration of concentrations alone, when states as above.

#### d. Toxicological Results:

Number and arrangement of goats in trench and in open shown in diagram in original report.

Position	No. of	Casualties	Percentage	Remarks
		Dead : Severe : light	died : Severe : Class in-cluding : died	
		48 hours : Class : A or B		
Trench	8	1 : 3	14 : 57	of 8 rats, 6 died
In open				
at 50 yd.	5	0 : 2	0 : 20	of 5 rats, 2 died
75 yards	4	0 : 0	0 : 0	of 4 rats, 2 died
100 "	3	0 : 0	0 : 0	of 3 rats, 0 died

One goat was killed by a splinter.

Observation on travel of phosgene -

Cloud travel North West - odor persisted 1200 yards from trenches, limit of detection by odor or test paper 200 yards.

c. Comparison

this trial (phosgene 9) with phosgene experiment 2.

	Phosgene 2	Phosgene 9
Wind velocity, miles per hour	1 - 3	3 - 1
Temperature - Wet bulb °F.	56.5	40.
Dry   "   "	58.	43.
Ground   "	50.	38.
Accuracy of shooting	very good	excellent
Percentage deaths	89	14
Percentage deaths and severe casualties	100	57
Average concentration of phosgene	2.945 mg./l.	0.679 mg./l.
Bursting charge	21 gramotetryl 2 ox. smoke pellet	

Failure of trial due to use of smoke pellet for opening the shell.

(C. I. P. 126. (4708)

(2) / Report on firing trial of 4.5" Howitzer C. I. Mark I shell filled phosgene (0 536).

a. Method

Artillery Data

Time of trial - May 18, 1918 - 3:30 P.M.

Map range, yards - 1750  
Front engaged, yards - 40  
Effective area, yards - 40x50  
Rounds fired - 50  
Rounds in effective area - 36  
Rate of fire, R.P. - 5 sec.  
Time to fire all rounds - 6 minutes 15 seconds

Firing trial conducted in bright sunshine and ground temperature higher than air, conditions usually considered unfavorable due to upward dissipation of the gas.

b. Meteorological Data:

Barometer - 29.90 inches  
 Temperature, dry bulb - 71. °F.  
                   wet " - 60. °F.  
                   ground - 76. °F.  
 Wind direction - NEW  
                   " velocity - 3 - 7, mean 5 miles per hour  
 Sky - blue  
 Rainfall, during experiment - nil  
                   previous 24 hours - nil  
 Weather - fine, bright sunshine

c. Field Results:

Position (see original)	Concentrations of phosgene.										Liquid phosgene in ccs. per cubic meter.
	Time after explosion		Height above trench		Concentrations		1 part in				
	Min.	Sec.	Ft.	In.	Mg./ liter						
1	1	5	4	0	8.90						
3	"	"	"	"	30.72	500			6.217		
5	"	"	1	8	11.74	150			21.45		
8	"	"	4	0	nil	390			8.200		
10	"	"	"	"	3.92						
12	"	"	"	"	0.09	1200			2.738		
15	"	"	1	8	0.45	50000			0.063		
18	"	"	4	0	0.09	10000			0.314		
20	"	"	"	"	2.16	50000			0.063		
23	"	"	"	"	0.20	2000			1.509		
25	"	"	1	8	0.17	25000			0.140		
26	"	"	4	0	0.20	25000			0.119		
1	1	55	1	8	0.17	25000			0.140		
3	"	"	4	0	0.74	25000			0.119		
5	"	"	"	"	2.47	5000			0.517		
8	"	"	"	"	0.61	1800			1.725		
10	"	"	"	"	0.13	7000			0.426		
12	"	"	"	"	0.62	35000			0.091		
14	"	"	1	8	0.19	7000			0.433		
16	"	"	4	0	0.09	2500			0.133		
18	"	"	"	"	trace	50000			0.063		
23	"	"	"	"	nil						
25	"	"	"	"	trace						
27	"	"	"	"	0.08						
21°	"	"	"	"	nil	60000			0.066		

Position (See original)	Time after explosion or 1st shell Min.	Height above trench floor Sec. Ft. In.	Concentrations mg./l. 1 part in	Liquid phosgene in ccs. per cubic meter
2	3	12	4 : 0 : nil	---
4	"	"	" : " : 16.01	280 : 11.21
7	"	"	" : " : 3.12	1500 : 2.179
9	"	"	" : " : trace	---
11	"	"	" : " : nil	---
14	"	"	" : " : 0.19	25000 : 0.133
17	"	"	" : " : 0.87	5000 : 0.608
19	"	"	" : " : 0.50	9000 : 0.346
21	"	"	" : " : 0.45	10000 : 0.314
22	"	"	" : " : 0.09	50000 : 0.063
24	"	"	" : " : 0.08	60000 : 0.056
30*	"	"	" : " : nil	---
2	4	3	" : " : trace	---
4	"	"	" : " : 96.26	46 : 68.63
7	"	"	" : " : 5.70	800 : 5.961
9	"	"	" : " : 3.65	1200 : 2.599
11	"	"	" : " : 0.91	5000 : 6.635
13	"	"	" : " : 1.13	4000 : 0.789
16	"	"	" : " : 0.54	8000 : 0.377
17	"	"	" : " : 0.23	20000 : 0.161
20	"	"	" : " : 0.17	25000 : 0.119
24	"	"	" : " : 0.45	10000 : 0.314
26	"	"	" : " : 0.27	17000 : 0.169
28**	"	"	" : " : nil	---
29**	"	"	" : " : trace	---

\* Samples positions 30 and 31 were taken 50 yards from trench, 1'8" above ground.

\*\* Samples positions 28 and 29 were taken in dugouts, 1'8" above floor.

#### General average concentrations.

Sector	Samples Nos.	G.A.C.	Concentration not	Remarks
No.	for diagram lines	/lines	included in G.A.C.	
1	1 - 5	4.0145	122.44 and 96.00	The concentrations not in-
2	6 - 12	2.3243	-----	cluded in the general were
3	13 - 20	0.4207	-----	obtained in close proximity
4	21 - 27	0.1766	-----	to and immediately after the
				burst of direct hits.

#### d. Toxicological Results:

For diagrams showing positions of animals and sampling bottles see original report.

Position	No. of goats	Casualties				Percentages	
		dead in 48 hours	Severe class	Light class	Dead	Severe class including dead	
In trench	7	1	3	3	14.3	57	
In dugout	1	0	1	0	0	100	
In open at 50 yards	3	0	0	3	0	0	
At 75 yards	2	0	0	2	0	0	
At 100 "	2	0	0	2	0	0	

Position	No. rats	Dead, Gassed, Normal, % dead and gassed			
		at 48 yards			
In trench	7	7	0	0	100
In open at 50 yards	6	1	3	1	80
At 75 yards	2	1	0	1	50
" 100 "	2	1	0	1	50

Observations on travel of phosgene vapors.

Detected by observers 500 yards down wind - traces 500 yards.

#### e. Remarks:

1. General trend of the phosgene vapor was to rise from ground in its passage to and over the trench. Observers 500 yards away were not wearing masks, whereas, in recent trials phosgene caused lachrymation at 1750 yards.

2. Results better than anticipated; rats more sensitive than goats; casualties on goats due to local high concentrations of direct hits.

3. Results show that bombardment in sunshine might be successful some tests needed for conclusions.

(3) D.C.P. 216, (3991)

(3) Report on the simultaneous firing of gas and H.E. shell. 1 - 4.5" howitzer Mark X shell filling phosgene, and 18 P.D.R.Q.F. service H.E. shell.

a. Object: To see whether effects produced by gas shell are seriously impaired by simultaneous firing of H.E. shell.

b. Method: Two squares 60 by 60 yards, with caged guinea pigs at 10 yards intervals.

c. Metacological Data:

Date of Experiment	-	3-12-18	3-20-18
Time of day	-	12:30 P.M.	6:00 P.M.
Barometer, inches		29.70	30.06
Temperature - wet bulb °F.		50	45.6
dry " "		55	47
ground		59	38
Wind, direction		S-W	W
velocity, miles per hour		3-7	4-7
Rainfall, during experiment		nil	nil
previous 24 hours		nil	nil

d. Toxicological Results:

(See diagrams, original report).

	No. animals	Killed	Severe casualties	Gassed	Normal	% Killed, severe gassed	% Killed, severe Normal, casualties,
Phosgene only	45	8	4	21	12	18	73
Phosgene plus H.E.	44	2	12	17	13	4	70
Phosgene only	48	12	3	16	17	25	65
Phosgene plus H.E.	45	23	1	8	11	53	76

e. Mark

Conditions of first experiment - not altogether favorable, ground temperature higher than air temperature, causing upward convection currents.

Conditions of second experiment - phosgene plus high explosive showed more casualties from gas than phosgene only very significant.

F. Conclusions:

1. No doubt that 18 pdr. H.E. may be used in conjunction with 4.5" howitzer shell, filled with phosgene, without diminishing the effect of the phosgene.

2. The 18 pdr. H.E. shell may be fired round for round with the 4.5" phosgene shell, and certainly in the proportion of 4 H.E. shell to 5 phosgene shell.

17. C.O.P. 42. (4328)

Experiments to determine concentration of gas produced in trenches by the explosion of 6" trench howitzers, cast iron, Mark I, bomb filled with phosgene.

a. Methods

Artillery Data:

Bombs used - 6" T.H. cast iron Mark I.  
Filling - Phosgene (C 548)  
Bursting - 10 grams Sphorite  
Ignition - No. 8 detonator sleeves, filled R.F.G. 2, for electric ignition.

Bombs exploded at rest:

Fragmentation - Well opened.  
Path of cloud - Travelled well over the trench, and visible up to 300 yards down wind.

b. Metacological Data:

Temperature of the air:

Dry bulb - 47°F.  
Wet " - 44.5°F.  
Temperature of ground: 53°F.  
Wind velocity: 6 miles per hour  
Direction of wind: N.-N.E.  
Sky: Blue - cloudy  
Rainfall: Nil during experiment - trace during previous 24 hours.  
Weather: Fine  
Barometric Pressure: 29.6 inches  
Time of day: 11:50 A.M.

c. Field Results:

On surface (1 foot 2 inches above ground level).

Sample	Position No.	Time after explosion of bombs at which samples were taken	CONCENTRATIONS	
			g./liter	Volume of air containing one volume phosgene both at N.T.P.
1	1	4 Sec.	2.11	2100
2	2	4 "	4.07	1100
3	3	4 "	2.58	1800
4	4	4 "	10.09	450



In trench						CONCENTRATIONS	
Sam- ple No.	Position No.	Time after explosion of bombs at which samples were taken		Height above floor of trench at which sam- ples were taken		Mg./liter	Volume of air con- taining one volume of phosgene.
		Min.	Sec.	Feet	Inches		
5	1	0	10	4	6	25.32	190
6	1	0	15	3	6	16.71	270
7	1	0	20	2	6	19.72	230
8	1	0	30	1	6	8.24	1400
9	1	0	45	1	6	1.24	3700
10	1	1	0	1	6	0.62	7300
11	1	1	15	1	6	0.36	13000
12	1	1	30	1	6	0.12	40000
13	2	0	10	4	6	11.19	400
14	2	0	15	3	6	18.66	240
15	2	0	20	2	6	8.58	500
16	2	0	30	1	6	1.35	3400
17	2	0	45	1	6	0.72	6000
18	2	1	0	1	6	0.45	10000
19	2	1	15	1	6	0.43	11000
20	2	1	30	1	6	0.08	60000
21	3	0	10	4	6	10.27	440
22	3	0	15	3	6	21.78	210
23	3	0	20	2	6	6.58	700
24	3	0	30	1	6	1.07	5200
25	3	0	45	1	6	0.16	30000
26	3	1	0	1	6	trace	---
27	3	1	15	1	6	nil	---
28	3	1	30	1	6	trace	---
29	4	0	10	4	6	19.89	230
30	4	0	15	3	6	10.15	450
31	4	0	20	2	6	7.67	590
32	4	0	30	1	6	1.76	2600
33	4	0	45	1	6	0.28	16000
34	4	1	0	1	6	0.23	20000
35	4	1	15	1	6	0.15	30000
36	4	1	30	1	6	0.40	11000

<u>In dugout</u>							
Sample No.	Position No.	Time after explosion of bombs at which samples were taken	Height above floor of trench at which samples were taken		Mg./liter	CONCENTRATION	
			Min.	Sec.		Volume of air containing one volume phosgene both at N.T.P.	
			Feet	Inches			
37	center	1	0	1	8	0.09	50000
38	of dug-	2	0	1	8	0.83	15000
39	out	5	0	1	8	2.01	1600
40		4	0	1	8	0.61	7000
41		6	0	1	8	0.80	6000
42		8	0	1	8	0.44	10000
43		10	0	1	8	0.68	5000
44		40	0	1	8	nil	---

d. Toxicological Results.

Observations in Dugout.

A white cloud penetrated to the foot of the eastern shaft in 20 seconds after the explosion of the bombs, and to the foot of the western shaft in 50 seconds; phosgene was detected at the center of the dugout in 26 seconds in amount sufficient to necessitate wearing a respirator. Lachrymatory effects of an intense nature were produced when the eyes were exposed at 3, 6 and 14 minutes after zero. At 26 minutes after zero the odor of phosgene was perceptible in the trench, and phosgene vapor in fairly strong concentrations was encountered half-way down the eastern and western shafts when the dugout was entered. At 65 minutes after zero phosgene was just detectable by smell in the dugout, but no discomfort was caused by the atmosphere.

e. Remarks:

The samples on the top of the parapet (Nos. 1-4) were evidently taken before the densest part of the cloud had reached the positions.

In three minutes phosgene was present in the dugout in fairly high concentration. From that time until after 10 minutes there was a fairly high concentration of phosgene moving backwards and forwards over the sampling position in the center of the dugout.

### Experiment II.

a. Method One 6-inch T.H. cast iron Mark I bomb, filled with phosgene, (0.548), was exploded at the bottom of a trench, and samples of the atmosphere were collected.

### b. Metacological Data:

Wind velocity	-	5 to 6 miles per hour
Wind direction	-	N.-E.N.W.
Temperature of air:		
Dry bulb	-	50°F.
wet "	-	45°F.
Temperature of ground:	-	58°F.
Rainfall	-	Nil during experiment and previous 24 hours
Weather	-	fine
Barometric pressure	-	29.69 inches
Time of day	-	10:50 A.M.

### c. Field Results:

#### In trench

Sample No.	Position No.	Time after explosion of bombs at which samples were taken		Height above floor of trench at which samples were taken		CONCENTRATIONS	
						Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
		Min.	Sec.	Feet	Inches		
1	R1	0	15	1	8	10.61	430
2	R1	0	20	4	0	18.34	250
3	R1	0	50	1	8	11.09	410
4	R1	0	55	4	0	3.09	1500
5	R2	0	35	1	8	1.89	2400
6	R2	0	40	4	0	4.96	900
7	R2	1	10	1	8	24.44	190
8	R2	1	15	4	0	5.41	840
9	R3	0	20	1	8	13.75	330
10	R3	0	20	4	0	5.05	900
11	R3	0	45	1	8	33.22	140
12	R3	0	45	4	0	7.52	600
13	R3	2	0	1	8	2.70	1700
14	R3	2	0	4	0	1.57	2900

Sample No.	Position No.	Time after explosion of bombs at which samples were taken		Height above floor of trench at which samples were taken		CONCENTRATIONS	
		Min.	Sec.	Feet	Inches	Mg./liter	Volume of air containing one volume phosgene both at H.T.P.
15	R4	0	35	1	8	19.87	230
16	R4	0	35	4	0	4.99	900
17	R4	0	55	1	8	18.81	240
18	R4	0	55	4	0	13.27	340
19	L1	0	15	1	8	2.21	2000
20	L1	0	20	4	0	2.43	1900
21	L1	0	50	1	8	49.46	92
22	L1	0	55	4	0	22.59	200
23	L2	0	35	1	8	1.92	2400
24	L2	0	40	4	0	1.08	4200
25	L2	1	10	1	8	41.80	110
26	L2	1	15	4	0	10.75	420
27	L3	0	20	1	8	34.72	54
28	L3	0	20	4	0	31.79	140
29	L3	0	45	1	8	23.18	200
30	L3	0	45	4	0	27.71	160
31	L3	2	0	1	8	3.87	1200
32	L3	2	0	4	0	3.28	1400
33	L4	0	30	1	8	31.39	140
34	L4	0	30	4	0	17.43	260
35	L4	1	10	1	8	6.02	800
36	L4	1	10	4	0	9.23	500

In duct

Sample No.	Position No.	Time after explosion of bombs at which samples were taken		Height above floor of trench at which samples were taken		CONCENTRATIONS	
		Min.	Sec.	Feet	Inches	Mg./liter	Volume of air containing one volume phosgene both at H.T.P.
39		1	0	1	8	25.72	170
40	cen-	2	0	1	8	22.54	200
41	ter	3	0	1	8	20.14	220
42	of	5	0	1	8	15.78	270
43	dug-	10	0	1	8	8.81	500
44	out	15	0	1	8	5.40	800
45	30	30	0	1	8	2.92	1600
		Mins.	Min.				
46	foot of east side.	1	0	1	8	0.64	7000
47		1	0	1	8	0.61	7000
48	center	1	30	1	8	0.13	35000
49	of	2	0	1	8	0.09	50000
50	dugout	8	0	1	8	nil	---

d. Field Results:

Observations:

The bomb opened well and a good volume of cloud was thrown up and out of the trench. The actual bay in which the bomb was exploded was clear of visible cloud in 75 seconds, but visible vapors were still present in two adjoining bays at 2 minutes. The bay on the eastern side was not clear of mist until 3 minutes after the explosion of the bomb.

A dense cloud of phosgene immediately penetrated down both the eastern and western shafts; it was impossible to see across the dugout owing to the opacity of the cloud. At 60 minutes after zero a cloud of considerable opacity was still present in the dugout. At 90 minutes after zero it was just becoming possible to see across the dugout, although fumes were still present in the bottom of both shafts. At 120 minutes after zero phosgene vapors were detected on reaching the fourth step down each shaft of the dugout and visible fumes were still in the dugout. At 180 minutes after zero the dugout was free from phosgene, but traces of hydrochloric acid were detected.

e. Remarks:

The concentrations reported show a travel of vapor of phosgene in high concentration along the trench on both sides of the bay in which the bomb was exploded. The highest concentrations were  $1/32$  at position L1 at 50 seconds and  $1/54$  at position L3 at 20 seconds after zero. At one minute after zero phosgene was present in the dugout in concentrations  $1/180$ , and at the end of 30 minutes the concentration had fallen to  $1/1600$ . At 2 hours  $1/50000$  phosgene was present.

18. C.C.P. 216. (4021)

Report on Firing Trial of 4.5" Horitzer C.I. Mark K  
Shell, Filled Phosgene.

a. Method.

Time of trial: March 15, 1918 at 5:45 P.M.

Artillery Detachment

More rapid firing with higher wind velocity  
than usual.

Max range 1750 yards - Front engaged 40 yards.  
Effective area 40 x 30 yards - Rounds fired 59  
(9 ranges).  
Rounds in effective area 31 - Rate of fire 8.F.  
2 seconds.  
Time taken to fire all rounds 2 minutes 15 seconds.

b. Metereological Data

Barometer - 29.99 inches  
Thermometer: dry bulb 47°F.  
wet " 45°F.  
ground " 45°F.  
Wind - N.E. - S.W. velocity 8-6 miles per hour  
sky - blue  
Rainfall - None during exposure nor in previous  
24 hours.

c. Field Results

2,500 yards from trenches southwest of battery -  
strong odor, turned test paper, longest distance ever observed to travel  
at Porton. 3,000 yards (beyond woods) - not detected.

Position (sec dia- gram in original report	Time after burst of first shell when sample was taken	Height above floor of trench at which sample was taken	Sp./liter	Volume of air contain- ing volume of phosgene both at NTP	Volume of liquid fill- ing in eos. per cubic meter
	Secs.	Ft. Inches			
5	15	4 0	5.01	900	3.498
10	"	" "	0.11	40000	0.077
10	"	1 8	trace	-	-
15	"	4 0	nil	-	nil
19	"	1 8	nil	-	nil

Position (see dia- gram in original report)	Time after burst of first shell when sample was taken	Height above floor of trench at which sample was taken	Mg./liter	Volume of air containing 1 volume of phos- gene both at M.T.P.	Volume of liquid filling in cc. per cubic meter.
	Min. Sec.	Ft. In.			
19		15 4 0	trace	-	0
25		" " " "	0.52	6700	0.263
27		" " " "	2.83	1600	1.976
29		" " 1 8	1.05	4400	0.719
4		45 4 0	0.68	7000	0.475
8		" " 1 8	0.12	40000	0.084
9		" " 4 0	0.08	60000	0.056
14		" " " "	0.20	15000	0.210
16		" " 1 8	0.64	7000	0.447
18		" " 4 0	2.65	1700	1.850
23		" " " "	2.26	2000	1.579
27		" " 1 8	28.52	159	19.92
28		" " 4 0	0.57	7000	0.468
2	1	5 " "	1.22	3700	0.852
7	"	" " " "	0.46	10000	0.321
13	"	" " " "	0.20	25000	0.140
14	"	" " 1 8	0.92	4900	0.643
17	"	" " 4 0	0.78	6000	0.545
22	"	" " " "	0.17	25000	0.119
1	1	50 " "	trace	-	-
6	"	" " " "	0.51	9000	0.356
11	"	" " " "	0.35	15000	0.244
12	"	" " 1 8	0.25	17000	0.189
15	"	" " 4 0	0.17	25000	0.119
20	"	" " " "	0.55	8000	0.384
21	"	" " 1 8	0.95	4800	0.663
24	"	" " 4 0	1.53	3000	1.069
29	"	" " " "	0.12	40000	0.084
30 shelter dugout	"	" " 1 8	0.12	40000	0.084
31 deep dugout	"	" " above floor	0.08	60000	0.056
32 shelter dugout	"	" " of dugout	nil	-	-
3	Unknown	1 8	0.78	6000	0.545
6	"	" " " "	1.19	2800	0.831
24	"	" " " "	1.29	3500	0.901
26	"	4 0	11.74	386	8.200

d. Toxicological Results:

Fall of shell and arrangement of animals in diagrams,  
see original report.

Position	No. of goats used	Casualties			Percentage		Remarks
		Dead in 48 hrs.	Severe Class A or B	Light Class C	Dead	Severe casual- ties in cluding dead	
In trench	7	0	2	5	0	29	of 7 rats 0 died
In dugout	1	0	0	0	0	0	1 rat which survived
In open at 50 yards	5	0	0	3	0	0	of 5 rats 0 died
In open at 75 yards	4	1	1	1	25	50	of 4 rats 0 died
In open at 100 yards	3	0	0	1	0	0	of 3 rats 0 died



19. C.O.F. 215. (2485)

Report on firing trial of 4.5" howitzer cast iron shell filled with phosgene.

a. Method:

Time of trial - September 24, 1917- 5:40 P.M.

Artillery Details:

No. of experiment - 2  
Max range 1750 yards - front engaged 30 yards.  
Effective area 30x30 yards - rounds fired 36  
Rounds in effective area 21.  
" " " " from range table 25.  
Rate of fire - B.F. 5 seconds  
Time taken to fire all rounds - 4 minutes 30 seconds  
Direction of fire - frontal  
Accuracy of fire - very good  
No. howitzer used - 2  
Type of shell - C.I. with long narrow exploder tube  
Bursting charge - 21 grams trotyl  
Propellant 1st. chg. - ballistite  
Fuse - 44 Mark III x A  
Blind shell - 2 & 3 ricochet

b. Meteorological Data:

Barometer - 29.98 inches  
Thermometer - wet bulb - 56.5°F.  
dry " - 58°F.  
ground - 50°F.  
Wind direction - Between South West and South, South West.  
" velocity - 1-3 miles per hour  
Sky - blue  
Rainfall - nil during exposure and previous 24 hours

c. Field Results:

Position number see original report	Time after burst of first shell when sample was taken		Height above floor of trench at which sample was taken		CONCENTRATION	
	M.H.	Secs.	Feet	Inches	Mg./liter Phosgene	Volume of air containing one volume phosgene both at N.T.P.
4	2	0	4	0	4.45	1020
8	"	"	"	"	20.18	224
9	"	"	1	8	28.98	156
10	"	"	4	0	0.48	9430
12	"	"	1	8	7.54	600
14	"	"	4	0	5.02	902
2	4	0	"	"	1.24	2650
5	"	"	"	"	6.02	752
12	"	"	"	"	2.66	1700
15	"	"	1	8	3.09	1470
16	"	"	4	0	1.14	5970
1	4	20	"	"	0.69	6560
1	"	"	1	8	0.49	9240
3	"	"	4	0	0.68	6660
4	"	"	1	8	0.64	7070
5	"	"	"	"	1.97	2300
6	"	"	4	0	1.92	2360
7	"	"	"	"	8.27	548
11	"	"	"	"	1.56	2900
13	"	"	"	"	7.73	686
15	"	"	"	"	3.31	1370
17	"	"	"	"	0.36	12600
17	"	"	1	8	0.41	11000

Bottles at 8 and 9 showing 1/224 and 1/156 were opened soon after shell burst close by.

d. Toxicological Results:

Animal	No. used	Dead 48 hours	Casualties		Dead	Percentage
			Severe Class A or B	Slight Class C		
			In trench			
Goat	9	8	1 (A)	-	89	100
Rat	9	9	-	-	100	100

Code:

- (a) Severe casualty (A) probably die 3-4 days after bombardment.
- (b) Severe casualty (B) out of action for considerable period.
- (c) Light casualty (C) out of action for short period.

Of the 26 dead animals, twenty-two died within 14 hours after the trial. Of the 2 goats as casualties (A) would probably have died in another 24-48 hours. Since 75% of goats and 100% of rats exposed in open, 50 yards beyond the line of trench were killed, it follows that the lethal travel of cloud of phosgene liberated from 4.5" G. I. shell must be at least 50 yards and probably over 100 yards.

20. J.O.P. 216. (3670)

Report on firing trial of 4.5" C.I. Mark I  
howitzer filled phosgene.

a. Object: To test lethal qualities of phosgene.

b. Method:

Time: January 4, 1918 - 3:30 P.M.

Artillery Data:

No. of experiment - 6  
Number of rounds fired - 58 Map range, 1750 yards  
Front engaged, 40 yards Effective area, 40x30 yards  
No. of rounds in effective area, 36  
Rate of fire B.F., 5 seconds Total firing 9 minutes  
No. of rounds in effective area from range table, 34  
No. howitzer used, 2  
Type - C.I. Mk. I  
"Q" number - 0 476  
Bursting chg. - C - 10 (a)  
Propellant chg. - 2d Ballistite  
Fuse - #106  
Blind shell - 0

c. Metereological Data:

Barometer - 30.14 inches  
Temperature: wet bulb - 31.5°F.  
dry " - 32.5°F.  
ground - 30.5°F.  
Wind direction - West South West & South West  
" velocity - 7-1 miles per hour  
Sky - Cloudy  
Rainfall - nil during exposure or previous 24 hours

d. Field Results:

1. Observations on travel of phosgene vapor.

Direction of drift given by means of some W.P.  
shell fired at beginning and end of shoot give main drift slightly north  
of east.

Phosgene detected by odor and paper 1600 yards  
and 1800 yards from trenches. Limit of detection by odor and paper -  
2250 yards from trenches.

2. Concentrations of phosgene:						
Position number (see diagram in original report)	Time after burst of first shell when sample was taken		Height above floor trench at which sample was taken		CONCENTRATION	
	min.	Sec.	Ft.	Inches	Mg./liter	Volume of air containing 1 volume of phosgene both at N.T.P.
5	3	30	4	0	nil.	
10	"	"	"	"	1.15	4000
14	"	"	"	"	1.58	3000
15	"	"	1	8	1.94	2500
17	"	"	4	0	0.15	30000
21	"	"	"	"	0.46	10000
21	"	"	1	8	0.88	5000
27	"	"	4	0	0.66	5000
6	4	40	"	"	9.10	500
8	4	45	"	"	0.35	13000
4	"	"	1	8	2.59	1800
9	"	"	4	0	12.81	350
13	"	"	"	"	4.87	950
17	"	"	1	8	47.49	95
20	"	"	4	10	0.31	15000
25	"	"	"	"	0.68	6500
26	"	"	1	8	3.50	1300
7	6	5	4	0	0.20	23000
8	"	"	1	8	39.20	120
12	"	"	"	"	1.45	3000
15	"	"	4	0	0.36	5500
19	"	"	"	"	27.35	170
24	"	"	"	"	0.69	6500
29	"	"	"	"	0.65	7000
29	"	"	1	8	0.77	6000
1	8	0	4	0	0.68	7000
2	"	"	1	8	0.64	7000
10	"	"	"	"	0.60	7500
11	"	"	4	0	0.12	33000
15	"	"	"	"	2.29	2000
19	"	"	"	"	0.61	7500
22	"	"	1	8	11.32	400
22	"	"	4	0	0.67	5000
23	"	"	1	8	0.22	21000
23	"	"	4	0	0.45	10000
30 Shelter dugout	"	"	1	8 above floor of dugout	8.17	550
31 Deep dugout	"	"			2.86	2500
32 Shelter dugout.	"	"			0.42	11000

See diagram in original report for location of animals and containers.

c. Toxicological Results:

Position	No. of goats used	CASUALTIES			PERCENTAGE		Remarks
		Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casualties including dead	
In trench	6	3	3	0	50	100	Of 7 rats 6 died 1 rat died
In dugout	1	1	0	0	100	100	
In open at 50 yards	5	0*	0	3	0	0	Of 5 rats 0 died
In open at 75 yards	3	0	0	1	0	0	
In open at 100 yards	2	0	0	0	0	0	" 4 " 1 "
In open at 150 yards	0	-	-	-	-	-	" 3 " 0 "
							" 5 " 0 "

These figures exclude those animals which were wounded in shell fire.

\*Diagram shows goats #10 in the 50 yard as dead within 48 hours. The animal died mainly as result of septic inflammation of the legs - its lungs were classed C.

\*\*Note: Rats were probably used as controls in these tests.

No. of Experiment	1	2	3	4
Date	April 25, 1917	Sept. 24, 1917	Oct. 14, 1917	Jan. 4, 1918
Time of day	8 P.M.	5:40 P.M.	4:50 P.M.	3:30 P.M.
No. of 4.5" howitzer	2	2	2	2
Range in yards	1750	1750	1750	1750
Front engaged, yards	20	30	30	40
Number of rounds	25	30	42	58
Duration of firing	4 min. 0 Sec.	4 min. 30 Sec.	4 min.	9 min.
Muzzle velocity, miles per hour	5-10	1-3	0-1	7-4
Temperature of Wet bulb	45	56.5	43.5	31.5
Dry "	49.7	58	44.0	32.5
Ground	-	50	36.5	30.5
Percentage of goats in trench				
Killed	20	89	100	50
Killed and severe casualty	-	100	100	100

Kind of Experiment	1	2	3	4
Percentage of goats in dugout				
killed	-	0	100	100
Killed and severe casualty	-	100	100	100
— goats in open at 50 yards				
killed	-	75	0	0
Killed and severe casualty	-	100	0	0

f. General Conclusions:

1. Rigid conclusions regarding effect of low temperature impossible from comparing trial #6 with 2 and 3 because of other factors which largely influence the results.

2. Percent of deaths in relation to temperature.

In trench - 5% in trial 2 same order as in 3.

50 yards - greater in trial 2 although temperature 10° higher than in trial 3.

In trench - trial 3 double trial 6 when temperature was 10° lower.

3. Wind velocity as a factor.

Percent deaths should have greatest in trial 3, less in trial 2, least in trial 6.

(a) In trench - order as expected less in trial 2, least in trial 6.

(b) In open - greatest in trial 2 - accounted for by gas being slowly carried over the animals - no drifting.

g. Conclusions:

at temperatures between 32° and 58°F. shell filled with phosgene can be used with good effects in winds up to 7 miles per hour and that maximum effect will be exerted in winds of very low velocity and also definite direction.

21. C.C.P. 74.

Report on the correlation of the physiological and chemical data obtained in 8 artillery field experimental trials with phosgene.

a. Methods

Ordinary fire trench used.

Physiological Data:

Goats were used and results tabulated as follows:

Deaths (include all animals killed during shoot).

Severe casualties.

Light casualties.

Chemical Data: (Material tabulated and some observations on same).

Time of exposure - total time occupied by shoot, persistency of phosgene very slight.

Concentration - general average - C.A.C., approximate concentration of gas existing for the total period of the shoot in that particular portion of the trench where an animal was exposed.

Principles considered -

1. Number of samples taken during shoot - 30-50, opened in several series, 4-5, during shoot.

Time of firing - dependant on judgement of officer in charge samples from all parts of trench; general average of these unsatisfactory due to uneven distribution of gas in trench.

2. Found that traverses of trench from natural sectors, concentration of gas uniform throughout sector.

3. Unnecessary to discriminate between samples 4 ft. and 1 ft. 8 in. above the trench floor.

4. Concentration omitted immediately after shell burst accidentally within trench - raise local concentration temporarily above general average.

5. Results of field tests found to check very well with chamber experiments.



This report covers the following trials:

Trial No.	1	2	3	4	5	6	7	8
Trial Date	9-24-17	10-14-17	1-4-18	1-12-18	2-9-18	3-13-18	4-5-18	4-8-18
Reference	CCP 2463	CCP 2755	CCP	CCP	CCP	CCP	CCP	CCP
			3670	3370	3993	4021	4262	4262

Example of G.A.C. calculation - concentration as volume of air containing 1 volume of phosgene. (changed to mg./l.)

Number 3 shot.	Time after zero at which samples				Shell	Total
Sector (number of sampling positions in brackets)	were taken				bursts in trench	time of shoot
	3'30"	4'45"	6'5"	8'		
1 (1 - 8)	nil	0.3397	0.1920	0.6308	1(26.8166)	
		2.4533	*			
		8.832		0.6308		
2 (9 - 16)	1.104	12.617	1.472	0.1162		
	1.471	4.6434*	0.3029	0.5838	1(46.434)	9'0"
	1.766			2.808		
3 (17- 23)	0.1472	0.2944		0.2103		
	0.4416		*	0.5838	1(25.9764)	
	0.8832			0.8832		
				11.0400		
4 (24 - 29)	0.8832	0.6793	0.6793	0.4416		
		3.3969	0.6308			
			0.739			

Table 2 Correlating physiological and chemical data for 8 phosgene artillery shoots. Concentrations in  
Mg./liter.

No. of shoot	Sector concentration					Shell bursts in trenches	Actual casualties, sectors				
	1	2	3	4	5		1	2	3	4	5
1	4°30'	1.920	1.600	1.944		X(20.0727)	3 D	3 D	2 D		
2	4°0'	1.154	1.200	1.600		2(27.6)			1 S.C.		
						nil	3 D	3 D	3 D		
3	9°0'	1.92	1.76	1.84	1.077	X(36.8(1)					
						3(46.5(2)	1 D	1 D	1 S.C.	2 S.C.	
						(25.4(3)					
4	6°10'	0.177	0.402	0.512	0.158	X(26.9)	1 L&U	1 S.C.	1 D	1 D	
						2(11.04)		2 L&U	1 S.C.	1 S.C.	
5	2°16'	1.104	0.015	0.631	0.981	1X(27.8)	2 L&U	2 L&U	1 S.C.	1 S.C.	
									1 L&U		
6	11°0'	0.402	2.103	0.512	0.039	0.055	1 D	2 D	1 D	1 S.C.	3 L&U
7	2°40'	0.147	2.103	2.455	0.158	0.981	1 S.C.	2 D	2 D	1 S.C.	11 S.C.
									1 S.C.		
8	2°50'	0.110	0.920	2.24	1.262	X(16.36(2)	2 L&U	1 D	2 S.C.	1 S.C.	
						2(21.03(4)		1 S.C.			

X-shell burst; D-animals killed during shoot; S.C.-severe casualty; L&U-light casualties and animals not gassed.  
S.S. Concentrations calculated by method 1.

Groupings of results from experiments -

I Mainly deaths with some severe casualties, but no light casualties or unaffected.

II Mainly severe casualties together with a few deaths on the one hand, and some light casualties or unaffected on the other hand.

III Mainly light casualties and unaffected, with some severe casualties but no deaths.

Summary of results by groups -

Group	Deaths	Severe casualties	Light casualties, or unaffected
I	26	8	0
II	4	6	2
III	0	4	12

Table 2. A. Calculated by method 2. in %/l.

No. of shoot:	Time	Sector concentration					Shell bursts in trench	Actual casualties sectors				
		1	2	3	4	5		1	2	3	4	5
1	4'30"	2.944	3.68	3.154			(20.0727(2))	3 D	3 D	2 D		
							2(27.6)			1 S.C.		
2	4'0"	3.397	2.012	3.154			nil	3 D	3 D	3 D		
							(36.8(1))					
3	9'0"	1.162	3.154	1.338	1.003		3(46.5(2))	1 D	1 D	1 S.C.	2 S.C.	
							(25.4(3))					
4	6'10"	0.147	0.455	0.736	1.194		(26.9)	1 LCU	1 S.C.	1 D	1 D	
							2(11.04(4))		2 LCU	1 S.C.	1 S.C.	
5	2'18"	1.472	0.315	0.589	0.589		1(27.8(4))	2 LCU	2 LCU	1 S.C.	1 S.C.	
										1 LCU		
6	11'0"	3.397	1.840	0.491	0.059	0.063	nil	1 D	2 D	1 D	1 S.C.	3 LCU
											1 LCU	
7	2'40"	1.766	1.766	1.523	2.760	0.960	nil	1 S.C.	2 D	2 D	1 S.C.	1 S.C.
										1 S.C.		
8	2'50"	0.631	0.939	2.208	1.162		(16.36(2))	2 LCU	1 D	2 S.C.	1 S.C.	
							2(21.03(4))		1 S.C.			

H.B. Numbers in brackets are sector-numbers. D-animals killed during shoot; S.C.-severe casualties; LCU-light casualties and animals not gassed.

#### Summary of results, grouped.

Group	Deaths	Severe casualties	Light casualties and unaffected
I	21	7	0
II	8	5	2
III	1	6	12

See plotted results -

#### Conclusions-

1. Close concordance between chemical and physiological data.
2. Indicative of reliability of methods-field experiments in agreement with chamber experiments.
3. Method of calculating G.A.O. reliable, method 1 more accurate.

# - zero time taken from burst of first shell.

\* - Indicates direct hit in sector of trench at time stated.

General average concentration for period of shoot calculated and stated  
for each sector.

Sector	G.C.C. Mg./l.	Shell bursts not included in G.C.C.	Total time period of shoot
1	1.920	35.8166 mg./l.	
2	2.760	46.484 "	
3	1.840	25.9764 "	9'0"
4	1.077	-	

Table No. 1

Report No.	1	2	3	4	5	6	7	8
Calibre	4.5"	4.5"	4.5"	5"	4.5"	4.5"	4.5"	4.5"
Data	Sept. 24: Oct. 14	Jan. 4,	Jan. 12,	Mar. 9:	Mar. 13:	Mar. 4,	Apr. 8	
	: 1917 : 1917	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918
Reference	: C.C.P. : C.C.P.	: C.C.P.	: C.C.P.	: C.C.P.	: C.C.P.	: C.C.P.	: C.C.P.	: C.C.P.
	: 2465 : 2735	: 3670	: 3370	: 3993	: 4021	: 4262	: 4262	
Dated	: Oct. 2, : Nov. 11	: Jan. 3,	: Jan. 30,	: Mar. 4,	: Apr. 6,	: May 2,	: Apr. 8,	
	: 1917 : 1917	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918
File No.	: XLII, 29: XLII, 34	: XLII, 44	: XLII, 41	: XLII, 53: XLII, 54:				
Shell type	: C.I. : C.I.	: C.I.	: C.I.	: C.I. : C.I.	: C.I.	: C.I.	: C.I.	: C.I.
	: Mk. V : Mk. X	: Mk. X	: Mk. X	: Mk. X : Mk. X	: Mk. X	: Mk. X	: Mk. X	: Mk. X
Burster	: 21 dr. : C.L.C.	: C.I.C.	: C(b)	: 1 smoke: C.I.C.	: C.I.C.	: C.I.C.	: C.I.C.	
	: trotyl : (a)	: (a)		: pellet : (a)	: (a)	: (a)	: (a)	
No. rounds	: 38	: 52	: 58	: 22	: 51	: 59	: 50	: 50
Front yards	: 30	: 30	: 40	: 40	: 40	: 40	: 40	: 40
Time taken	: 4'30"	: 4'0"	: 9'0"	: 11'0"	: 6'10"	: 2'18"	: 2'40"	: 2'50"
Range yards	: 1750	: 1750	: 1750	: 4000	: 1750	: 1250	: 1750	: 1750
Temperature°	:	:	:	:	:	:	:	:
wet bulb	: 55.5	: 43.5	: 51.5	: 37	: 40	: 45	: 49	: 44
dry "	: 55	: 44	: 32.5	: 33	: 43	: 47	: 54	: 46
ground	: 50	: 35.5	: 30.5	: 35	: 38	: 45	: 50	: 44
Wind velocity: l-5	: 1-5	: 10-1	: 7-4	: 7-4	: 3-1	: 6-8	: 4	: 5-6
Conditions	: clear	: humid	: cloudy	: cloudy	: blue sky	: blue sky	: cloudy	: cloudy

(2755)  
22. C.C.P. 216. (C.W.C. 78).

Report on firing trial of 4.5" cast iron howitzer shell filled with phosgene.

a. Method:

Time - October 14, 1917 - 4:50 P.M.

Artillery:

Map range - 1750 yards - Front engaged 30 yards

Effective area 30x30 yards - Rounds fired 42

Rounds in effective area 27

" " " " from range table 29

Rate of fire - battery-fire 3 seconds

Time taken to fire all rounds - 4 minutes

b. Metereological Data:

Barometer - 29.46 inches

Thermometer, wet bulb - 43.5°F.

dry " - 44.0°F.

ground - 36.5°F.

Wind - North, North East-North, North West

velocity 0-1 miles per hour with period of complete calm.

Sky - Blue, cloudy

Rainfall - nil during experimental. 0.01 inches during previous 24 hours.

c. Field Results

Detected 1200 yards South East of trenches by color and paper.

Position Number (see original report)	Time after burst of first shell when sample was taken		Height above floor of trench at which sample was taken		Concentrations	
	Min.	Sec.	Ft.	Inches	Mg./liter phosgene	Volume of air containing one volume of phosgene both at N.T.P.
5	1	0	4	0	4.12	1100
5	"	"	1	8	5.08	896
9	"	"	4	0	4.48	826
12	"	"	"	"	4.69	965
18	"	"	"	"	0.24	18900
4	2	0	"	"	5.27	859
8	"	"	"	"	13.16	344
10	"	"	"	"	10.59	428
11	"	"	"	"	6.06	747
13	"	"	"	"	5.74	789
14	"	"	1	8	trace	-
17	"	"	4	0	1.21	3740
2	2	50	"	"	2.30	1970
4	"	"	"	"	1.65	2740
7	"	"	"	"	5.92	765
7	"	"	1	8	22.01	206
14	"	"	4	0	10.76	420
16	"	"	"	"	trace	-
1	3	45	"	"	0.08	56600
1	"	"	1	8	4.50	1010
3	"	"	4	0	1.77	2560
6	"	"	"	"	4.24	1070
15	"	"	"	"	4.25	1070
19	"	"	"	"	8.26	548
20 dugout	"	"	1	8 above floor of dugout	trace	-
21 "	"	"	1	8 "	50.48	129

d. Toxicological Results:

Arrangement of animals shown in diagram - see original report.

Position Gouts	No. used	Casualties			Percentage		Remarks
		Dead in 48 hrs.	Severe class A or B	Light Class C	Dead	Severe casualties including deaths	
In trench	9	9	0	0	100	100	Of 9 rats 9 died
In dugout	1	1	0	0	100	100	One rat died
In open at 50 yards	4	0	0	3			Of 5 rats 5 died
In open at 100 yards	3	0	0	2	0	0	Of 3 rats none died

Of the 10 dead animals, 9 died within 16 hours and the other soon afterwards. Greater humidity of atmosphere may cause decomposition of phosgene, so that the sphere of lethal travel is restricted.

e. Remarks:

Concentration higher than in G.C.P. 2463. The figure 1/149 in dugout at 3 minutes-45 seconds is highest yet recorded.

23. C.C.P. 106.

Report on firing trial of 6" O.I. howitzer shell filled  
phosgene.

a. Method:

Time - Saturday, July 27, 1918 - 8:05 P.M.

Artillery Details:

No. 6" howitzer used -2  
Type C.I. "C" No. of shell C. 589  
Bursting charge C (b); propellant charge 2d. H.C.T.  
Fuse 106 III. Blind shell - 0  
Map range (yards) 4000 - target engaged 40x40.  
Rounds fired (exclusive of ranges) 21 - rate of fire B.F. 25sec/  
Time taken to fire all rounds 4 minutes 20 seconds -  
accuracy very good.

b. Metecorological Data:

Barometer - 29.75 inches  
Thermometer, dry bulb - 53°F.  
                  wet " - 56°F.  
                  ground - 54°F.  
Wind - Variable, drift to dead calm.  
Sky - Overcast.  
Rainfall - nil. during experiment - 0.04 in. during pre-  
                  vious 24 hours.  
General Conditions - very favorable, muggy and misty after  
                  warm afternoon - grass very damp from previous  
                  rain.

c. Field Results: Analytical figures.

Sample	Description	No.	Phosgene calculated from		True phosgene value	
			total chlorine	mg./liter	mg. per liter	Volume of air containing 1 volume of phosgene.
			mg./liter	volumes of air containing 1 volume of phosgene.		
Samples opened near square	1		0.25	18000	0.13	35000
15 minutes after end of shoot	2		0.19	25000	0.13	35000
Samples opened 850 yards from target	1		0.04	100000		
3/4 hour after end of shoot	2		0.04	100000		
	3		0.04	100000		
	4		0.04	100000		



#### d. Toxicological Results:

Guinea pigs - one pig on every 8 square yards in series in cages 4 feet above ground level.

Number exposed - 49 Number killed 49 Percent killed - 100  
Result due to blanketing effect of phosgene.

Travel of vapor:

1. 300 yards - from target - necessary to wear masks for 20 minutes.

2. Artillery trenches - 150 yards south.

20 goats and 20 rats in position.

14 rats died, 5 goats light casualties.

3. Ford van containing 54 guinea pigs (Killed - 4  
(Gassed - 27

200 yards from target - 10 min.

860 " (third portion) - 39 min.

lethal concentration phosgene 40 min.

exposure, being  $4/50,000$ .

24. C.C.P. 216. (5594)

Report on experiments to determine the concentration of gas produced in the open by the explosion of 4.5" howitzers cast iron shell filled with phosgene.

a. Object:

To determine concentration of phosgene at varying distances from point of shell burst.

b. Time of Trial:

July 30, 1918 - 7:15 P.M.

c. Meteorological Data:

Barometer - 29.85 inches

Thermometer - dry bulb - 70°F.

wet " - 68°F.

ground - 69°F.

Wind direction - South South East

" velocity - 1st exposure - 5 1/2 miles per hour

2nd " - 5 1/2 " " "

Sky - blue

Rainfall - nil. during exposure or previous 24 hours

Weather - fine

EXPERIMENT NO. 1: 1 shell exploded at rest in open.

a. Method: Observers under cover 15 yards down wind from point of burst, immediately after explosion emerged and took sample from jets breast high - 15 yards from point bursting shell.

A visible cloud was formed which moved quickly down wind. Doubtful whether any other than first samples were taken in main cloud as wind velocity was rather higher.

b. Field Results:

Observer No.	Sample No.	Time after explosion of shell at which sample was taken	Concentration	
			Hg./liter phosgene	Volume of air containing one volume of phosgene both at H.T.P.
1	1	Approximately 5 sec.		
	2	" 7 "	0.34	13000
	3	" 9 "	0.38	12000
2	4	" 5 "	0.32	14000
	5	" 7 "	2.64	1700
	6	" 9 "	0.46	10000
3	7	" 5 "	0.98	4500
	8	" 7 "	2.04	2200
	9	" 9 "	0.08	60000
			trace	

It is considered that concentration shown by 4 and 7 are representation of main cloud.

EXPERIMENT NO. II.

a. Method: 3 shells in line at intervals of 1 yard in open and exploded simultaneously.

b. Field Results:

Observer Number	Sample Number	Distance from point of burst of shell yards	Time of explosion of shell at which sample was taken Seconds	Concentrations	
				Mg./liter phosgene	Volume of air containing one volume of phosgene both at N.T.P.
1	1	15 yards	Approximately 5	0.08	60000
	2	"	"	3.67	1200
	3	"	"	0.97	4700
1a	4	"	"	5	1.69
	5	"	"	7	1.28
	6	"	"	9	1.60
1b	7	"	"	5	4.50
	8	"	"	7	2.66
	9	"	"	9	2.86
2	10	25	"	11	1.04
	11	"	"	13	0.95
	12	"	"	15	0.72
2a	13	"	"	11	1.31
	14	"	"	13	1.21
	15	"	"	15	0.81
2b	16	"	"	11	3.93
	17	"	"	13	1.54
	18	"	"	15	0.66
3	19	50	"	25	2.49
	20	"	"	27	2.16
	21	"	"	30	1.66
3a	22	"	"	25	2.53
	23	"	"	27	1.43
	24	"	"	30	1.26
3b	25	"	"	25	1.60
	26	"	"	27	1.48
	27	"	"	30	1.43

d. Remarks:

Eliminating sample No. 1 which was obviously out of the cloud.

General Average Concentration

Distance	G.A.C.	Highest Concentration at the distance
15 yards	1/1900 2.324 mg./l.	1/1000 4.416 mg./l.
25 "	1/3400 1.2988 "	1/1200 3.68 "
50 "	1/2500 1.766 "	1/1800 2.453 "

e. Summary of Results:

- I. Where one 4.5" howitzer east iron - concentration 1/2000 at 15 yards, 2.208 mg./l.
- II. Where three 4.5" howitzer east iron - concentration 1/1000, 1/1200, 1/1800, etc., distance 15, 25, 50 yards, 4.416, 3.68 and 2.453 mg./l.  
General average concentration - 1/1900, 1/3400, 1/2500, 2.324, 1.2988 and 1.766 mg./l.

25. G.C.P. 216. (1398)

Report on experiments with C.I. 4.5" howitzer shell  
Mark I, filled phosgene.

EXPERIMENT NO. 11

a. Methods:

Time of firing - April 25, 1917 - 8:10 P.M.

ARTILLERY DETAILS:

10 shells fitted with #18 electric fuses, 2 rows - one  
10 yards, 2nd 11 yards from trench shells, 2 yards apart in each row.

No. 1 failed to explode.

b. Metacological Data:

Barometer - 30.20 inches

Thermometer - wet bulb @ 45.5°F.  
dry " - 51.5°F.

Wind direction @ North East  
" velocity - 6 miles per hour

Sky - clear, blue

Rainfall - Nil during experiment or during previous twenty  
hours.

c. Field Results:

SAMPLES TAKEN FIVE SECONDS AFTER EXPLOSION ON PARAPET OF TRENCH.

Position Number (see ori- ginal dis- gram)	Concentrations	
	mg./liter	Volume of air containing one volume phosgene both at M.T.P.
1	0.24	
2	11.51	18900
3	16.97	400
4	20.84	267
5		217
Bottle broken by shellsplinters.		

Position Number (see ori- ginal Report diagram)	Time after explosion of shell		Height above bottom of trench at which sample was taken		Concentrations	
	Min.	Sec.	Ft.	Inches	Mg./liter	Volume of air contain- ing one volume phosgene both at N.T.P.
1		10	4	6	trace	-
1		15	3	6	"	-
1		20	2	6	"	-
1		30	1	6	"	-
1		45	1	8	0.08	55600
1	1	0	1	8	0.08	55600
1	1	15	"	"	trace	-
1	1	30	"	"	nil.	-
2		10	4	6	8.25	725
2		15	3	6	2.94	1540
2		20	2	6	1.55	2920
2		30	1	6	0.90	5030
2		45	1	8	0.31	14600
2	1	0	1	8	0.91	4980
2	1	15	"	"	0.28	16200
2	1	30	"	"	0.36	12600
3		10	4	6	16.83	269
3		15	3	6	18.20	249
3		20	2	6	11.40	397
3		30	1	6	6.37	711
3		45	1	8	0.32	14200
3	1	0	"	"	0.47	9830
3	1	15	"	"	0.32	14200
3	1	30	"	"	0.24	18900
4		10	4	6	11.16	406
4		15	3	6	12.07	375
4		20	2	6	12.73	356
4		30	1	6	11.31	400
4		45	1	8	7.10	638
4	1	0	"	"	0.75	6040
4	1	15	"	"	0.31	14600
4	1	30	"	"	0.27	16800
5		10	4	6	3.87	1170
5		15	3	6	6.22	728
5		20	2	6	4.58	938
5		30	1	6	15.33	295
5		45	1	8	4.77	949
5	1	0	"	"	1.25	3620
5	1	15	"	"	0.88	5140
5	1	30	"	"	trace	-

Position Number	Time after explosion Min. Sec.	Height above bottom of trench	Mg./liter phosgene	Volume of air containing one volume phosgene at N.T.P.
	30	1 ft. 8 in. above	0.08	56600
1	30	floor level of	trace	-
1	30	dugout capacity	0.19	23800
2	30	1272 cubic feet	trace	-
3	30	floor of dugout	"	-
4	30	21 ft. 6 in. below	0.08	56600
6	0	ground level	0.08	56600

d. Remarks:

1. Concentration in trench high for 30-45 seconds - then rapid fall surprising low.

2. Established point that phosgene can be liberated from explosion of cast iron artillery shell in such a manner as to sink into trench. Probably concentration could not be as great in actual artillery fire.

EXPERIMENT NO. II.

Trial of the effect in animals in trench by 4.5" howitzer cast iron shell, filled with phosgene when fired from gun.

a. Methods:

Time of trial - Wednesday, April 25, 1917 - 8:00 P.M.

Artillery details:

No. and type of guns - Two 4.5" howitzer  
Average weight of shell 34 lbs. 6 ozs.  
Propellant charge - 1st charge  
Fuse 44 Mark III - X4  
Blind shell - 1  
Bursting charge - 5 drams trotyl  
Map range 1750 yards - front engaged 20 yards  
Effective area 20 x 30 yards - rounds fired 25  
Rounds in effective area 13 - rate of fire 3 rounds -  
B.F. 2 seconds with pauses  
Time taken to fire all rounds - 4 minutes  
Accuracy of shooting - good

b. Meteorological Data:

Barometer - 30.2 inches

Thermometer - wet bulb - 45°F.  
dry " - 49.7°F.

Wind velocity - 5-10 miles per hour  
" direction - North East

Sky - Overcast

Rainfall - Nil during exposure & previous 24 hours.

c. Toxicological Results (See diagram in original report).

	No. in trench	Dead within 24 hours	Dead within 48 hours	Dead within 72 hours	Total dead	Percentage dead
Goats	7	2	-	-	2	28
Rabbits	7	-	-	-	0	0
Rats or Mice	8	4	2	-	6	75

d. Remarks:

Wind unsteady - most part velocity 5 miles per hour  
frequent gusts .10 miles per hour on 20 yard front - 25 - 4.5" howitzer  
shell are required.-each holding 944 cc. of liquid.



26. C.O.P. 216. (4202)

Report on firing trials of 4.5" howitzer C.I. mark X shell filled with phosgene.

a. Object:

To study effects with lower wind velocity - compare report 4021. Previous results had shown that effects produced were only slight at this velocity.

b. Methods:

Artillery Details:

No. of trial	13	14
No. of 4.5" howitzers used	6	6
Type of shell	C.I. Mark X	C.I. Mark X
Map range - yards	1750	1750
Front engaged - yards	40	40
Effective area	40 x 30	40 x 30
Rounds fired (ranges not included)	50	50
Rounds in effective area	27	33
Predicted ditto	34	34
Rate of fire	gun fire	Section fire 10"
Time taken to fire all rounds	2'40"	2'50"
Direction of fire	enfilade	Frontal
Accuracy of shooting	good	very good
Bursting charge	C.I.C. (a)	C.I.C. (a)
Propellant "	2d	2d
Fuse	106 Mk. III	106 Mk. III
Blind shell	0	0

c. Meteorological Data:

No. of trial	13 - Apr. 5, 1918	14 - Apr. 6, 1918
No. of 4.5" Howitzer	6:40 P.M.	7:00 P.M.
Barometer inches	29.73	29.35
Thermometer dry bulb	54°	48°
wet "	49°	44°
ground.	50	44
Wind direction	West North West	North North East
velocity	mainly 4	North East 3 - 6
Sky	blue - cloudy	Blue - cloudy
Rainfall - during experiment	nil.	nil.
during previous 24 hours	trace	0.01 inches
General conditions	very favorable	favorable

d. Toxicological Results:

1. Observations on Travel of Phosgene Vapor.

Trial 13:

1750 yards from trenches - detected by slight lachrymation and test paper (burned paper yellow).  
2300 yards from trenches - limit beyond which not detected.

Trial 14:

1760 yards from trenches - detected by strong odor - no lachrymation.  
2200 yards from trenches - traces detected by smell - no indication on paper.

2. Physiological Details:

See original report for arrangement of animals.

Trial 13, Goats:

Position	No. of goats used	Casualties			Percentages	
		Dead in 48 hours	Severe Glass A or B	Light Glass C	Dead	Severe casualties including dead
In trench	8	4	4	0	50	100
In open at 50 yards	5	0	1	1	0	20
In open at 75 yards	4	0	0	0	0	0
In open at 100 yards	3	0	0	1	0	0

Trial 14 Goats:

In trench	7	1	4	2	14	71
In dugout	1	0	0	0	0	0
In open at 50 yards	4	0	0	2	0	0
In open at 75 yards	4	0	0	1	0	0
In open at 100 yards	3	0	0	1	0	0

Trial 13 Rats:

In trench	8	7	0	1	87	87
In open at 50 yards	2	1	1	0	50	100
In open at 75 yards	3	0	0	3	0	0
In open at 100 yards	1	0	0	1	0	0

Trial No. 14 Rats						
Position	No. of goats used	Casualties			Percentages	
		Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casualties including dead
In trench	7	6	0	1	86	86
In open at 50 yards	5	2	1	2	40	60
" " " 75 "	4	1	1	2	25	50
" " " 100 "	3	1	0	2	33	33

N.B. - In trial 13, due to slight wind change from that prevailing when animals were placed in position the majority in open were not in direct path of the cloud.

#### c. Field Results

Position number see original diagram	Time after explosion of first shell at which sample was taken	Height above floor of trench at which sample was taken	Mg./liter phosgene	Volume of liquid air containing one volume phosphogene both at N.T.P. sample
	Min.	Sec.	Ft.	Inches
1		20	4	0
3		"	1	8
7		"	4	0
12		"	"	"
16		"	"	"
19		"	1	8
23		"	4	0
24		"	1	8
25		45	4	0
26		"	1	8
27		"	4	0
5	1	50	"	"
9	"	"	"	"
11	"	"	1	8
13	"	"	4	0
19	"	"	"	"
22	"	"	"	"
26	2	40	1	8
4	"	"	4	0
8	"	"	1	8
10	"	"	4	0
13	"	"	1	8
14	"	"	4	0

Position number see origi- nal diagram	Time after explosion of first shell at which sam- ple was taken	Height above floor of trench at which sample was taken	Mg./liter	Volume of air containing one volume phosgene both at N.T.P.	Liquid filling phosgene in cos. per cubic meter of sample
	Min.	Sec.	Feet	Inches	
16	2	40	1	8	nil.
18	"	"	4	0	trace
21	"	"	"	"	-
21	"	"	1	8	0.56
25	"	"	4	0	8000
28 dugout	"	"	1	8	0.56
29 "	"	"	1	8	8000
					0.22
					20000
					0.154
					nil.
					"
					"
					"

Sector	Samples Numbers	General Average Concentration - Volumes of air containing one volume of phosgene both at N.T.P.	Time of shot
1	1-4	30000*	
2	5-11	2100	
3	12-20	1800	
4	21-25	2800	
5	26-27	4500	

2 Mins. 40 Secs.

\*-Shell burst very close to trench at end of shoot which may have given high late concentration. G.A.C. for whole period - 3000.

Trial 14.							
Position Number (see original report diagram)	Time after explosion of first shell when sample was taken	Height above floor of trench at which sample was taken	Mg./liter phosgene	Volume of air containing 1 volume phosgene both at K.T.P.	Liquid filling phosgene in cos. per cubic meter of sample.		
	Min.	Sec.	Ft.	Inches			
5		25	4	0	nil.	-	-
10		"	"	"	0.84	5000	0.587
11		"	1	8	1.28	3500	0.894
15		"	4	0	0.55	8000	0.384
20		"	1	8	0.24	19000	0.168
21		"	4	0	0.89	5000	0.622
27		"	"	"	0.40	11000	0.279
4	1	20	"	"	nil.	-	-
17	"	"	1	8	0.24	19000	0.168
9	"	"	4	0	1.03	4400	0.719
19	"	"	"	"	trace	-	-
23	"	"	"	"	8.90	500	6.216
26	"	"	1	8	1.98	2300	1.359
28	"	"	4	0	1.50	3000	1.047
33*	"	"	-	-	nil.	-	-
54*	"	"	-	-	0.89	12000	0.272
55*	"	"	-	-	0.18	25000	0.125
2	0	0	4	0	nil.	-	-
3	"	"	1	8	0.32	14000	0.224
6	"	"	1	8	0.51	15000	0.217
8	"	"	1	8	0.75	6000	0.524
12	"	"	1	8	0.52	9000	0.363
16	"	"	4	0	0.78	6000	0.545
20	"	"	1	8	0.76	6000	0.531
22	"	"	4	0	1.88	3300	0.950
29	"	35	1	8	0.18	25000	0.125
1	"	"	1	8	nil.	-	-
6	"	"	4	0	0.12	40000	0.084
7	"	"	"	"	0.26	17000	0.182
13	"	"	1	8	2.90	1600	2.025
14	"	"	4	0	0.12	40000	0.084
18	"	"	1	8	4.52	1000	3.017
25	"	"	4	0	4.74	1000	3.311
23	"	"	"	"	1.92	2400	1.841
26	"	"	"	"	0.68	7000	0.476
29	"	"	"	"	trace	-	-
30 Shelter dugout	"	"	"	"	0.16	30000	0.112
31 Deep dugout	"	"	"	"	0.91	5000	0.635
32 Shelter dugout	"	"	"	"	16.67	271	11.640
12	unknown	4	0	"	21.83	207	15.250
24	"	"	"	"			

\* Samples taken 50 yards from trench at 1 ft. 8 inches above ground level.

Trench Sector	Sample numbers in sector	Time of shoot	General Average Concentration stated as volumes of air containing one volume phosgene		Shell burst concentration not included in sector figures	
1	1-8	2 Min.	40000	0.1104 Mg./l.		
2	9-17	50 Sec.	4800	0.92 "	270	16.355 Mg./l.
3	18-25		1900	2.324 "		
4	26-29		3500	1.2617 "	210	22.03 "

Sectors 2, 3 and 4, which show the effective area covered by the cloud give a general average concentration of 2900., 1.5227 Mg./l.  
 General average concentration for total period: 3800, 1.162 mg./l.

f. General Remarks:

1. Weather conditions - less favorable in trial 14 - variable wind.
2. Artillery - distribution better in trial 13 than in trial 14 because Northern end of target received much less attention than Southern end. No. of shells fell short.
3. Concentrations phosgene - not so high in 14.
4. Animal casualties - high percent deaths and severe casualties - localized in trench.

g. Conclusions:

1. A surprise shoot with 50 rounds on 40 yards at 1750 yards map range may be expected to render majority of occupants of target either deaths or severe casualties.
2. Require very accurate shooting and favorable weather. Most favorable wind 4 miles per hour or under.

27. C.W. & 110.

a. Object:

To determine which is the most suitable nature of shell to employ for "surprise" shoots, 18 pr., 4.5", or 6" howitzers.

b. Metamorphological Data:

Wind velocity -  $4\frac{1}{2}$  - 10 miles per hour

Ground temperature - Lower than air temperature  
(exact temperature not stated)

Weather conditions - generally favorable.

c. Field Tests:

Comparative firing trials of 18 mdr., 4.5" How. and 6" How. shell filled phosphene (p.9).

	Trial I			Trial II			Trial III		
	18 pdr.	4.5" How.	6" How.	18 Pdr.	4.5" How.	6" How.	18 Pdr.	4.5" How.	6"
No. of guns or hows. used	4	4	2	4	3	2	4	3	2
Typ of shell	C.I.	C.I. <u>XI</u>	C.I.	C.I.	C.I. <u>X</u>	C.I.	C.I.	C.I. <u>X</u>	C.I.
Bursting charge	Fuse only	(C.I.C.) (a)	C (b)	Fuse only	C.I.C. (a)	C (b)	Fuse only	C.I.C. (a)	C (b)
Fuse	106 III	106 III	106 III	106 III	106 III	106 III	106 III	106 IIIA	106 <u>ZZZ</u>
Max range in yards	4050	4050	4050	4050	4050	4050	4050	4050	4050
Target engaged	50x50	50x50	50x50	50x50	50x50	50x50	50x50	50x50	50x50
No. of rounds fired	70	35	17	43	25	10	39	23	9
Rate of fire	B.F. 1 sec.	B.F. 3 sec.	B.F. 10 sec.	3rds. G.F.	B.F. 2 sec.	B.F. 15 sec.	B.F. 3 sec.	B.F. 3 Sec.	B.F. 15 sec.
Time taken to fire	4 min.	4 min.	2 min.	1 min.	1 min.	2 min.	2 min.	1 min.	1 min.
all rounds	2 sec.	3 sec.	57 sec.	35 sec.	45 sec.	15 sec.	20 sec.	57 sec.	50 sec.
Accuracy of shooting	very good	very good	excellent	poor	very good	good	very good	very good	good
Volume of phosphene used (liter)	34.3	29.3	37.3	22.	21	20	19.7	19.3	19.7



#### d. Toxicological Results.

Animals: Caged guinea pigs in each target at 10 yard intervals.

Calibre of gun	Litres of phosgene effective	Casualties		Proportional percentage of casualties per 10 liters phosgene taken in each case	
		Killed	Killed & gassed	Killed	Killed & gassed
I 18-pr.	24	14/34	24/34	17	29
4.5"	17	4/29	21/29	8	42.5
6"	55	25/29	23/29	26	27
II 18-pr.	9	2/34	3/34	5.5	10
4.5"	15	1/35	3/35	2.0	6
6"	13	4/36	6/36	7.5	11.5
III 18-pr.	12	3/32	8/32	7.7	20.8
4.5"	13.5	4/33	12/33	10.5	30.0
6"	15.0	21/36	25/36	32.0	39/7

#### e. Conclusions.

6" howitzer shell filled phosgene superior to either 18 pr. gun shell or 4.5" howitzer shell, filled phosgene under varying conditions of time and weather.

28. C.W.C. 51. C.L.P. 1453

Use of chlorpicrin and phosgene mixtures in field gun and howitzer shell.

a. Methods

Artillery Details

Shells - 4.5" Howitzer, steel, C.T.

Number of shells - 50

Filling - Chlorpicrin 75% - Phosgene 25%

Front engaged - trench, 40 yards from four howitzers

Booster charge - 16 grams tetryl surrounded by paraffin wax

Fuse - No. 106

Time of firing - 4 minutes, 53 seconds

Shell falling in effective area - 23 out of 50.

b. Toxicological Results:

Kind of Animals	No. in trench	Dead within 24 hours	Dead within 48 hours	Dead within 72 hours	Total dead	Percent dead
Goats	14	9	0	1	10	71
Rabbits	8	4	3	0	7	87
Rats	14	14	0	0	14	100

Two goats in a dugout - did not die within 72 hours, although 1 did so half a day later.

Pathological examination showed damage to lungs and blood, sufficient to render animals which live unfit for physical exercise.

c. Field Results

Mixture does not give adequate smoke for ranging purposes.

Criticism: The work on goats is repeated in C.W.C. 77. The data given here is very meagre, especially that pertaining to meteorological conditions. Some additional data is given in C.W.C. 77 but whether or not this is applicable to the whole of this work is not known.

29. C.C.P. 217.

Report of firing trials of 4.5" howitzer shell filled with phosgene and chlorpicrin.

Trial No. 21.

a. Methods

April 24, 1917 - 6:45 P.M.

Artillery Details:

Number and type of guns used, two 4.5" howitzer  
Average weight of shell, 34 lbs. 8 ozs.  
Map range, 1700 yards. Front engaged, 40 yards  
Effective area, 40 by 30 yds. Rounds fired 70.  
Rounds in effective area, 42.  
Rate of fire, 3 rounds B.F. 2 seconds with pause  
Time taken to fire all rounds, 10 minutes 23 seconds  
Accuracy of fire, very good  
Direction of fire, endilade  
Bursting charge, 5 drams T.M.T.  
Fuse 44 Mark III x A  
Blind shell - I

b. Metacological Data:

Barometer - 30.2 inches  
Thermometer - wet bulb - 45.7°F.  
                  dry " - 50.2°F  
Wind direction - W.N.W.  
                  velocity - 5 miles per hour  
Sky - clouding over after fine day  
Rainfall - none during test, or during previous 24 hours

c. Toxicological Results:

Animals	No. in trench	Dead 24 hrs.	Dead 48 hrs.	Dead 72 hrs.	Total dead	Percent dead
Goats	13	7	-	-	7	54
Rabbits	14	-	1	-	1	7
Mice	11	10	-	-	10	91

d. Results:

The results are attributed to:

1. Low bursting charge. The mixture was not sufficiently atomized.
2. Relative efficiency factor of clouds formed from the 4.5" C.I. shell, holding 625 cc. and the steel container holding 944 cc. The cast iron shell is not as efficient as the steel container.

Attention is called to the low mortality among the rabbits used.

Trial No. 5:

a. Object:

To get further information regarding rate of fire.

b. Method:

April 26, 1917 - 8:00 P.M.

Artillery Details:

No. and type of guns used, one 4.5" howitzer  
Average weight of shell, 34 lbs. 9 ozs.  
Propellant charge, 1st charge  
Bursting charge, 16 drams trotyl  
Map range, 1750 yards  
Front engaged, 20 yards  
Effective area, 20 x 30 yards  
Rounds fired, 25  
Rounds in effective area, 13  
Rate of fire, B.F. 20 seconds  
Time to fire all rounds, 13 minutes 36 seconds  
Fuse, 44 Mark III x A  
Blind shell, 1  
Direction of fire - enfilade  
Accuracy of fire, very good.

c. Metacorological Data:

Barometer - 30.2 inches

Thermometer - wet bulb - 45.6°F.

dry " - 49.1°F.

Wind, direction - W. (unsteady)  
velocity - 2 miles per hour

Sky, overcast, rainfall, none during experiment, or  
previous 24 hours.

d. Toxicological Results:

Animal	No. in trench	Dead in 24 hrs.	Dead in 48 hrs.	Dead in 72 hrs.	Total Dead	Percent dead
Goats	7	7	-	-	7	100
Rabbits	7	4	1	-	5	71
Mice	7	7	-	-	7	100

e. Conclusions:

13 shell fell in the effective area and 3 burst in a group south of effective area. These were effective because when they burst the wind had changed to southwest and the clouds formed were swept right along the line of the trench.

The shell did not give adequate smoke for ranging purposes.

The gas appeared to hang about the trench much more than in trial #2 and 15 minutes after firing had ceased there was still a distinct haze in the trench.

This was the slowest rate of fire so far tried and gave the best results with phosgene and chlorpicrin and one of the best results recorded in any trial.

30. A.E.F. 178 (C.W.G. 77).

Persistency of a mixture of phosgene and chloropicrin liberated from artillery shell.

a. Methods

Artillery Data:

Shells: Steel, 4.5", container type  
How fired: From four howitzers  
Range: 2400 yards  
Time to fire all rounds: 11 minutes  
Collection of Samples: Samples of atmosphere in the woods, and in the open, where concentrations of chemicals were highest.

b. Metecorological Data:

Wind velocity - 5 to 7 miles per hour.

c. Toxicological Results:

1. Toxic Effects on Animals:

Of six goats exposed and examined, two were found to be suffering from gas poisoning. The pathological examinations showed that three goats might be classed as light casualties.

2. Toxic Effects on Observers:

Strong lachrymation was experienced one minute after cessation of fire. Eight minutes after firing, lachrymation was experienced near the ground. 57 minutes after the last burst, the woods were free from vapors.

d. Conclusions:

Much greater under surface persistency was to be expected in an area previously bombarded than in fresh soil. At least five days should elapse after bombardment with shell filled with chloropicrin and phosgene, before unprotected troops dig themselves in.

Criticism: P.G., the mixture used in these tests, is apparently a definite mixture but the proportions of phosgene and chloropicrin are not known.

51. Richter, Burrell, Clayton, Oglesby, Kuhn.  
(P.T. VIII-1390)

Report on 50/50 mixture of chlorpicrin and phosgene  
fired statically from a Livens projectile.

a. Object:

To determine the lethal area in trenches from detonations of Livens projectiles, containing 50 percent chlorpicrin and fifty percent of phosgene.

b. Methods:

Livens projectiles containing 12 liters of a mixture were fired statically in a trench. 6 oz. black powder used as booster. Eight dogs at 20 foot intervals on each of the projectile were exposed for thirty minutes.

Artillery Data:

Time of firing: 8:54 a.m. 12/5/18  
Extent of gas cloud: 164 feet to left of projectile/  
80 feet to right of projectile.  
Lethal area: 144 feet to left of projectile.  
40 feet to right of projectile.  
Separation of gases: After some distance, the phosgene was ahead.

c. Meteorological Data:

Wind velocity: At time of firing, nil. Average for the first five minutes one mile per hour.  
Temperature of air:  
In trench - 53°F.  
Ground in trench - 51.8°F.  
Weather: Not given.  
Relative humidity: 94%  
Barometric pressure: 29.88 inches.

d. Field Results:

Arrangement of samplers: Eight groups of ten samplers each were placed twenty feet apart for a distance of 100 feet, to the right and left of the projectile.

CONCENTRATIONS														
Concentration in Mx./l. Chlorine					Concentration in Mx./l. Phosgene					Concentration in Mx./l. Chloroform				
Intervals in Seconds					Intervals in Seconds					Intervals in Seconds				
10	30	60	180	300	10	30	60	180	300	10	30	60	180	300
.00	.53	4.00	1.70	.00	.00	—	—	1.40	.00	.00	—	—	1.08	.00
4.45	9.06	.91	.63	1.17	—	6.69	.64	.07	.23	—	6.69	.64	.89	1.54
10.73	10.15	1.55	.62	.57	11.20	—	1.09	.46	—	3.98	—	1.17	.45	—
8.48	8.39	5.65	5.22	3.80	7.03	7.38	—	5.20	3.18	5.22	4.69	—	2.25	2.31
2.76	—	6.36	.42	10.85	1.05	4.94	5.02	8.46	5.69	3.03	—	4.19	—	10.38
.42	—	.83	.96	2.92	—	.00	.64	—	1.20	—	—	.57	—	5.16
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	—	—	—	.12
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00



A large part of the cloud rolled out over the trenches, settled to the ground and advanced so as to fill the trench and on over the ground in an easterly direction. After four minutes this part of the cloud had advanced beyond the trench system. The main part of the cloud, according to the observation of the eye, climbed out of the trench 160 feet to the left, and 50 feet to the right of the projectile.

In this list it must be kept in mind that a higher concentration is generally realized in the part of the trench occupied by the dogs than at the top of the sample bottle.

After twenty minutes it was impossible for men to enter the trench without masks, within 50 feet to the right, and 150 feet to the left of the projectile. At this time the odor of phosgene, could still be distinguished, although that of chlorpicrin was still predominant.

After twenty-five minutes one could advance to the distance of fifteen feet from the crater, from the left side of the projectile and to the right to about 100 feet from the crater without appreciable discomfort.

#### e. Toxicological Results:

Position	Symptoms	Effects
160 feet, left	Lachrymation, depression, salivation	Severe casualty
140 " "	" " "	"
" "	trembling, rapid and shallow respiration	Death in 12 hours
120 " "	Sneezing, lachrymation, salivation, increased nasal discharge, retching	Death in 12 hours
100 " "	Salivation, lachrymation, retching, dyspnoea	Death in 5 hours
80 " "	Salivation, lachrymation, nasal discharge, dyspnoea.	Death in 12 hours
60 " "	Lachrymation, salivation, retching, dyspnoea.	Death in 12 hours
40 " "	Salivation, lachrymation, retching, vomiting, dyspnoea.	Death during exposure
20 " "	Wildly excited, salivation, lachrymation, vomiting, gasping.	Death during exposure
20 feet right	Wildly excited, salivation, lachrymation, retching, vomiting.	Death during exposure
40 " "	Excitement, collapse, lachrymation, salivation, retching, vomiting.	Death in 10 hours
60 " "	Lachrymation, salivation, marked depression.	Severe casualty
80 " "	Lachrymation, salivation	Light casualty
100-160 feet	None	Unaffected.

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f. Conclusions:

The lethal area from Livens, with a 50/50 mixture of phosgene and chlorpicrin is 180 feet.

Dogs showed symptoms of phosgene only, 60 and 80 feet to the left, and 160 feet to the right of the projectile.

(32). C.C.P. 2.

Report of firing trial of 60 pdr. cast iron shell filled with phosgene and chlorpicrin.

Animals used, cats and goats.

a. Object:

To show the marked results which can be obtained from a few well placed shell, filled with P.G., at low temperature (27.5°F). (The shooting in this trial was the worst ever witnessed at Porton).

b. Method:

Time - December 19, 1917 - 3:30 P.M.

Artillery Data:

Map range - 1750 yards. Front engaged - 40 yards.  
Effective area - 40x30 yards. No. rounds - 32.  
No. rounds in effective area - 7.  
Direction of fire - frontal.  
Accuracy - very poor. Time to fire all rounds - 9 Minutes.  
Rate of fire B.F. 15 seconds.

No. of experiment - 12  
No. of howitzer 5" used - 3  
Type of shell - C.I., R.L. design 25348A (1) with side filling hole and steel container to R.L.D. 3534 as used in steel shell.  
C Type number - C 374.  
Bursting charge - C (b)  
Propellant charge - 1st  
Fuse - 106.  
Blind shell - 0.

c. Metacriological Data:

Barometer - 29.96 inches  
Thermometer, wet bulb, 28.5°F.  
dry " 27.5°F.,  
ground 22°F.  
Wind - N.E., velocity - 3 miles per hour  
Sky - blue, cloudy  
Rainfall - none during experiment, none during previous 24 hours.

#### 4. Field Results:

Concentrations of Phosgene & Chlorpicrin.										
Position	Time after		Height		Concentrations					
	burst of		above		Phosgene			Chlorpicrin		
	1st shell		floor of		Mg./l.			Vol. of air		
	when sam-		strong		air cont.			cont. 1 vol.		
	ple was		at which		1 vol.			chlorpicrin		
	taken		sample		phosgene			both at		
	was taken		was taken		both at			N.T.P.		
	Min.	Sec.	Ft.	Inches						
2	1		45	4	0	0.13	34,800	0.15	48,900	
7	"	"	"	"	"	0.14	32,380	0.29	25,300	
8	"	"	"	1	8	trace	-	0.45	16,300	
12	"	"	"	4	0	0.15	30,200	0.69	10,600	
16	"	"	"	"	"	0.39	11,600	0.73	10,100	
18	"	"	"	1	8	nil.	-	0.14	52,400	
19	"	"	"	4	0	trace	-	0.70	10,500	
26	"	"	"	"	"	0.09	50,300	0.10	73,400	
27	"	"	"	1	8	0.08	56,600	0.09	81,600	
4	3		30	4	0	0.12	37,700	0.09	81,600	
9	"	"	"	"	"	0.25	18,100	0.56	15,100	
11	"	"	"	1	8	0.11	41,200	0.09	81,600	
13	"	"	"	4	0	trace	-	0.62	11,800	
17	"	"	"	"	"	1.14	3,940	0.82	8,950	
22	"	"	"	"	"	nil.	-	0.20	36,700	
24	"	"	"	1	8	nil.	-	0.14	52,400	
27	"	"	"	4	0	nil.	-	trace	-	
1	6		20	1	8	0.13	34,800	0.50	14,700	
5	"	"	"	4	0	0.40	11,300	0.26	28,200	
6	"	"	"	1	8	nil.	-	0.18	40,800	
10	"	"	"	4	0	trace	-	0.09	81,600	
14	"	"	"	"	"	nil.	-	0.25	29,400	
23	"	"	"	3	"	nil.	-	0.10	73,400	
28	"	"	"	1	8	0.64	7,070	1.04	7,060	
28	"	"	"	4	0	0.26	17,400	0.80	9,180	
1	9		40	"	"	nil.	-	0.25	29,400	
5	"	"	"	1	8	nil.	-	nil.	-	
6	"	"	"	4	0	trace	-	trace	-	
11	"	"	"	"	"	nil.	-	0.18	40,900	
15	"	"	"	"	"	trace	-	0.44	16,700	
20	"	"	"	"	"	0.08	56,600	0.78	9,410	
21	"	"	"	1	8	0.16	28,300	0.65	11,300	
25	"	"	"	4	0	0.29	15,600	1.15	6,380	
29	"	"	"	1	8	0.64	7,070	1.03	7,130	
Shelter	"	"	above floor							
dugout 30:	"	"	of dugout			0.11	41,200	0.14	52,400	
Deep	"	"								
dugout 31:	"	"	"			nil.	-	0.18	40,800	
Shelter	"	"								
dugout 32:	"	"	"			nil.	-	0.45	16,000	

e. Toxicological Results:

Position	No.	Dead in:	Severe:	Light:	% Dead:	% Severe:	Remarks
	Goats	48 hrs.	Class				
Trench	7	1	5	1	14	86	Of 4 cats 0 died
Dugout	1	0	0	1	0	0	
In open at							
50 yards	5	0	1	3	0	20	Of 3 cats 0 died
In open at							
75 yards	4	0	1	1	0	25	Of 3 cats 0 died
In open at							
100 yards	5	0	0	1	0	0	Of 3 cats 0 died

Though no cats died, autopsy showed one at 75 yards was severe casualty, one in trench light casualty.

Cats were used instead of rats because of the extremely cold weather.

Observation on travel of the phosgene vapor. Cloud seemed very slight to observers 1100 yards from the artillery trenches and was quite invisible long before it reached them.

The probable direction of drift had previously been shown by means of a smoke candle and with 2 observers moving backwards and forwards at right angles to the wind direction, the points of maximum density were probably found.

In the field 1100 yards from trenches, phosgene and chlorpicrin could be detected by smell and smarting of the eyes, phosgene by smell, by paper test and by slight "tobacco" reaction noticed by one observer. This observer on moving 200 yards further away from trench, lost all trace of the cloud.

f. General Observations:

Considering that only 7 shells fell in the effective area (one shell fell nearly on 50 yard line) it is remarkable that of 7 goats in the trenches, 1 was killed and 5 rendered severe casualties; that 1 out of 5 goats in the open at 50 yards from trench and 1 out of 4 goats in open at 75 yards from trench were also rendered severe casualties.

Average number of casualties in previous trials, 85% in this experiment, 86%.

g. Conclusions:

Phosgene can be used effectively in cold weather.

33. C.O.P. 3.

Firing trial of 4.5" howitzer shell, container type,  
filled phosgene and chlorpicrin.

a. Method:

Artillery Data:

Front 20 yards, map range 1750 yards  
Effective area 20x30 yards  
Rounds in effective area 15.

b. Metecorological Data:

Barometer - 30.07 inches  
Temperature, wet bulb - 41.5°F.  
dry " - 45°F.  
ground - 42°F.

Wind direction - S.W.  
" velocity - 7-8 miles per hour rising to 12 miles  
per hour.

Sky - overcast

Rainfall - none during experiment nor 24 hours previous.

c. Toxicological Results:

Position of rats	No.:	Dead in 48 hours	Severe casualty	Slight casualty	Remarks
In trench	4	0	0	2	4 rats 0 died
In dugout	1	0	0	1	
Open 50 yards	3	0	0	1	3 " 0 "
" 75 "	3	0	0	0	3 " 1 "
" 100 "	1	-	-	-	1 " 1 "

34. C.W.C. 95 - C.C.P. 6.

chlorpicrin.

Tests with 4 inch Stokes filled with phosgene and

a. Method:

Artillery Details:

1 Stokes mortar.

41 four inch bombs with service bursters fired from

Trench front 20 yards at 340 yard range.

Time taken to fire all rounds 1 hour 20 minutes.

Direction of fire, enfilade. Accuracy, fair.

b. Meteorological Data:

Ground temperature, 88°F.

in direction.

Wind velocity, 1 miles per hour, drifts variable

General conditions, very favorable.

c. Toxicological Results:

Position	No. of goats used	Dead in 48 hrs.	Severe casualties	Slight casualties	Percent- age	Remarks
			Class a or b	Class c	dead	
trench	8	8	0	0	100	9 rats 9 dead
dugout	1	1	0	0	100	1 " 1 "
In open at 50 yards	5	0	0	1	0	15 " 0 "
In open at 50 yards	3	0	0	0	0	13 " 0 "

Travel of cloud,  
300 yards from trench, phosgene strongly in evidence before chlorpicrin was detected.

800 yards from trench, still observed 25 minutes after last bomb.

d. Observations:

- (1) Highest concentration: phosgene 8.27 mg./l.  
chlorpicrin 8.40 mg./l.
- (2) All animals in trench killed.
- (3) Change in wind prevented gas from passing over animals in open.

25. Roberts, Clayton, Burrell, Oglesby.  
B.M. XXVI-28.

Concentrations, toxicity and persistency of a mixture of an  
chlorpicrin and phosgene fired statically from a Liven's projectile in a  
trench. Filler: 5.94 cc. chlorpicrin (90.1% pure) and 5940  
cc/  $\frac{1}{2}$  jpsgeme (98.1% pure).

a. Method:

Artillery Data:

Time of firing - October 18, 1918 - 8:55 A.M.  
Quantity of load - 11,880 ccs.  
Booster charge - 6 ounces of black powder.  
Fragmentation - well opened.

b. Metecrological Data:

Wind velocity - under 1 miles per hour.  
Temperature of air - 53° F.  
Temperature of ground - 51° F.  
Weather: clear  
Relative humidity - 94 percent  
Barometric pressure - 29.88 inches.

c. Field Results:

Concentration						
Concentration in cc./l. over five-minute period.						
Phosgene			Chlorpicrin			Distance from Drum
Max.	Min.	Ay.	Max.	Min.	Ay.	
1.40	.00	.47	1.06	.00	.36	100 feet to left
.00	.00	.00	.00	.00	.00	100 feet to right
6.69	.07	1.91	6.49	.09	2.40	60 feet to left
.08	.00	.01	.12	.06	.09	60 feet to right
11.20	.46	4.19	3.98	.45	1.90	40 feet to left
1.20	.00	.60	3.16	.57	1.06	40 feet to right
7.38	3.18	5.70	5.22	2.25	3.62	20 feet to left
8.46	1.05	5.08	10.36	3.08	5.88	20 feet to right

d. Toxicological Results:

No dogs died as a result of exposure to this mixture.



e. Results

Toxic concentration obtained over a front of 160 feet. Thirty-five minutes after firing, the men lachrymated 100 feet too the right, and fifteen feet to the left of the drum. Phosgene was not detected. One hour after, the trench was untenable 200 feet to the left of the drum, due to the shift in wind direction and velocity. Two hours after firing, chlorpicrin was not noticeable 80 feet to the right. It was unbearable fifteen feet to the right. Twenty-four hours after firing, it was unbearable five feet to either side of the projectile.

36. C.W.C. 51, 55 & 64.

a. Field Results:

Trial No.	S H E L L No.	Type	Bursting Charge	Range Yards	Front Engaged	Number Rounds	Duration of shoot	Direction of fire	Wind vel. miles per hour	Liters of chemicals from effective shell per yard front per mil.
							Min. Sec.			
1	4	St.Ctr.	16 dr. tetryl	1750	40	50	4 32	frontal	4	.13
2	2	CI MK I	5 dr."	1750	40	70	10 25	enfilade	5	.06
3	1	St.Ctr.	16dr."	1750	20	25	13 36	"	2	.06
4	4	St.Ctr.	Fumyl Ct(c)	1750	40	50	7 10	frontal	15-20	.11
55	2	St.Ctr.	"	1750	20	25	5 36	frontal	5-8	.10
6	2	St.Ctr.	"	1750	40	51	6 17	enfilade	6-1/2	.10
7	2	St.Ctr.	"	1750	40	50	7 9	frontal	4	.09
8	2	St.Ctr.	"	1750	40	50	6 35	frontal	nil.	.09

Note: With the exception of trial 5, in which the accuracy was "fair" all other trials were rated as "very good".

b. Toxicological Results:

Trial No.	Number of goats used	Percentage killed	Percentage severe casualties including killed
1	14	76	Unclassified
2	13	54	"
3	7	100	100
4	12	9	89
5	7	0	85
6	12	17	83
7	10	80	100
8	12	100	100

37. G. C. P. 176.

with Comparative firing trial of 6" V.I. howitzer shell filled  
(a) Chlorpicrin 80% - Stannic Chloride 20%  
(b) Phosgene - chlorpicrin.

a. Method:

Artillery Details:

Shells	Chlorpicrin 80% Stannic Chloride 20%	Phosgene- Chlorpicrin
Howitzer, 6"		
Number used:	1	1
Type	C.I.	C.I.
"C" Number of shells	0 1097	0 335
Bursting charge:	0 (c)	0 (c)
Propellant charge:	2nd Ballistite	2nd Ballistite
Fuse:	106 III	106 III
Blind shell:	0	0
Map range, in yards:	4050	4050
Target engaged in yards:	50x50	50x50
Rounds fired:	26	26
Rate of fire:	Time fired, 26 sec.	Gun fire 20 sec.
Time to fire all rounds:	11 minutes 22 seconds	9 minutes 42 seconds
Direction of fire:	frontal	frontal
Accuracy of shooting:	very good	very good

b. Metorological Data:

Wind velocity:	1 - 2 miles per hour
Direction of wind:	Mainly West
Temperature:	
Dry bulb:	66°F.
wet " :	61°F.
Temperature of ground:	56°F.
Barometric pressure:	30.06 inches
Sky:	blue
Rainfall:	nil. during experiment and previous 24 hours.
General conditions:	Favorable
Time of day:	7:50 p.m.

c. Toxicological Results:

With chlorpicrin eighty percent - Stannic chloride twenty percent.

Position	No. G. pigs	Number killed	Number gassed	Normal	Percent killed	Percent killed & gassed
On ground level	32	15	9	8	46	75
At 4 ft. level	17	6	6	5	35.3	70.6
Total	49	21	15	13	42	73

With phosgene and chlorpicrin

Position	No. G. pigs	Number killed	Number gassed	Normal	Percent killed	Percent killed & gassed
On ground level	34	9	12	13	26.5	61.7
At 4 ft. level	16	4	5	9	25	43.75
Total	50	13	17	22	26	56

d. Results:

In a series of field tests which have been previously described, phosgene and chlorpicrin have proved their superiority over chlorpicrin 80% - stannic chloride 20%. The results of the above trial are distinctly in favor of the latter mixture, however. One such trial, does not, however, prove that in 6" shells it is generally speaking more efficient than phosgene and chlorpicrin.

53. C.C.P. 205.

Experiments to determine the persistency of lethal gases in dugouts. Comparison of persistency of phosgene and chlorpicrin.

a. Method:

Two 4" U.I. Stokes bombs, filled with PG. (a mixture of phosgene and chlorpicrin) and fitted with four grams ophorite boosters, and No. 8 detonator sleeves, with electric igniters were placed in a trench, one mid-way between the two entrances to a deep dugout, the other immediately opposite one of the entrances. Both bombs opened well and exploded simultaneously.

b. Meteorological Data:

Wind velocity: 14 miles per hour.

Direction of winds: Northwest.

Temperature of air:

wet bulb - 42.5°F.

dry " - 44.6°F.

Temperature of ground - 43°F.

Sky - Overcast.

Rainfall - Nil. during experiment, .11 inch during previous 24 hours.

Barometric pressure - 29.15 inches.

c. Results:

At 45 seconds after firing, the maximum of concentration of phosgene in the dugout was 1.53 mg./l. At 1 minute and 30 seconds, the maximum concentration of chlorpicrin in the dugout was 2.20 mg./l. At 10 minutes, chlorpicrin was not longer present in quantitative amounts. At 50 minutes the lachrymatory atmosphere in the trench and at both entrances to the dugout was noticed. In one hour and fifty minutes, an unprotected observer could just enter both shafts. In 3 hours 20 minutes, an unprotected observer went almost to the bottom of both shafts before he lachrymated. He experienced severe lachrymation in the main chamber of the dugout. In 5 hours, 20 minutes, the dugout and shafts were clear of chlorpicrin.

d. Conclusions:

When 4" Stokes bombs, filled with B.G. burst in a trench near the entrance to a dugout, high concentrations of chlorpicrin may be produced in the dugout. The vapors of chlorpicrin persist in a dugout for a period of about six hours.

39. Kolls and Satler.  
P.T. VIII-A 398.

a. Object:

To note the comparative effect of clouds containing cyanogen chloride and phosgene under the same field conditions.

b. Methods:

Arrangement of field - see diagram in original report.  
8 Livens projectiles in a set fired simultaneously, moved to side of field just before firing due to change in direction of wind. Fragmentation good in all but one where there was a bad burst.

c. Meteorological Data:

Time of firing - 4:28 P.M.  
On range near 2400 yard line.  
Time - 4:30 P.M.  
Temperature of:  
surface of ground - 41.6  
altitude of 6 ft. - 43.0  
Relative humidity % - 63  
Barometric pressure, inches - 29.94  
Wind direction from - North West  
Wind velocity, miles per hr. at alt. 6 ft. - 4.3  
Sky - overcast with low strata - cumulus clouds moving North West.  
Ground - cool and moderately dry - no rains for 54 hours, slightly cooler than air above - gas clouds settled drifted along surface of ground.

d. Field Results:

Concentrations of phosgene and cyanogen chloride mixture in mg./l. total chlorine.

Distance : from drum:	1	2	3	4	5	6	7	8	9	10	11	12
100 feet	3.83	4.11	33.6	1.76	43.8	6.01	2.37	none	0.33	none	2.54	0.15
300 "	1.48	2.11	0.02	0.06	none	10.1	0.43	2.09	3.18	none	none	0.38
600 "	4.24	0.20	2.32	0.02	10.1	4.55	0.15	0.14	0.006	none	none	3.41
900 "	1	1	1	1	1	1	1	1	1	1	1	1
100 feet	Time in seconds - 14, 24, 34, and 54.											
300 "	" " " - 41, 51, 61, and 81.											
600 "	" " " - 82, 92, 102, and 122.											
900 "	" " " Hand pump - average 0.11 for 10 minutes - began 123 seconds.											

e. Results:

Mixture of phosgene and cyanogen chloride gave no pronounced immediate effects of cyanogen chloride due to the small quantity. Small number of delayed deaths - little effect of phosgene due to small quantity.

See tabulations on page 174.

The cyanogen chloride in mixture did not produce pronounced effects. Symptom mild in 1st row, 2 dogs and 1 guinea pig died on field. All others showed signs of gassing. 2nd row - Severely gassed - 2 dogs died on field. Other rows - mild casualties.

f. Conclusions:

A mixture of cyanogen chloride and phosgene is not as good as an equal amount of either gas alone, as determined by comparing the above test with tests of the pure gases.

40. C.C.P. 29. (3269)

Report on experiments to determine persistency of a mixture of phosgene and arsenic trichloride mark I after liberation from artillery shell. 4.5" howitzer shell, container type, filled with phosgene-arsenic trichloride mark I .358 cc.

a. Object:

To determine under surface and over surface persistency of C.B.R. Mark I.

b. Method:

Artillery Data:

Number of howitzers - 4; rounds fired - 100;  
Rate of fire - E.R. 5 sec. to 3 sec.;  
Time taken to fire all rounds - 8 minutes 30 seconds;  
Accuracy - good; rounds in effective area - 90;  
Type of shell & steel container; bursting charge - fumyl C(b)  
Propellant charge - 1st ballistite; fuse - #106;  
Blind shell - 3; Map range - 2300 yards;  
Bombarded area 140 - 60 yards.

c. Metereological Data:

Time	4:00 P.M.	4:30 P.M.
Barometer, inches	30.10	30.10
Thermometer, wet bulb	87	84.8
dry "	88	85.3
ground	82	28
Wind direction	W	W-SW
velocity, miles per hour	4	3-5
Sky	blue	blue
Rainfall	nil during experiment and 24 hours previous	

d. Toxicological Data:

Observers unable to detect phosgene 4 to 6 minutes after.  
5 guinea pigs exposed - no effect. 4 guinea pigs in, and one just  
to leeward of each crater.

e. Conclusions:

Under surface and over surface persistencies of phosgene  
negligible quantities. No samples taken for analysis.



(3348)

41. C.O.P. 219 (C.W.C. 89).

Report on firing trials of 4.5" cast iron howitzer shell filled phosgene and arsenic trichloride, Mark II.

a. Object.

To test value of C.B.R. Mark II, as compared with C.B.R. Mark I.

b. Methods.

Artillery Details:

	1	2	2	3
No. of 4.5" howitzers	2	2	2	5
Type of shell	steel container	D.D.	cast iron Mark X	steel container
Bursting charge	C (b)	D.D.(b)	CIC(c)	C(b)DD(b) CIC(a)
Max range, yards	1750	1750	1750	1750
Front engaged, yards	40	40	40	40
Effective area, yards	40x30	40x30	40x30	40x30
Rounds fired	55	52	56	65
Rounds in effective area	22	*	21	56
Rounds from range table	34	*	54	59
Rate of fire, R.P.	5 sec.	5 sec.	10 sec.	5 sec.
Time for to fire all rounds	5 min. 40 sec.	5 min. 40 sec.	8 min. 10 sec.	5 min. 10 sec.
Direction of fire	frontal	enfilade	frontal	frontal
Accuracy of shooting	poor	poor	good	very good
C No. of shell	393	394	395	(393 (394 (395
Propellant charge	1st Ballistite	1st Ballistite	2nd Ballistite	2nd Ballistite
Fuse	#106	106	106	106
Blind shell	0	0	0	0

\* Owing to frequent changes in wind directions and consequent alteration of line it is impossible to complete these details.

### c. Meteorological Data:

	1	2	3	4
Data	Dec. 11, 1917	Dec. 23, 1917	Dec. 27, 1917	Jan. 3, 1918
Time of day	5:50 P.M.	3:15 P.M.	3:30 P.M.	3:45 P.M.
Barometer, inches	30.11	30.09	29.95	29.98
Thermometer wet bulb	53.	32.	33.	34.5
dry "	54.	33	34.	35.5
ground	28.	29.	31.	34.
Wind direction	N.E.	N.W.S.W-W.N.W.	NNE	SW
velocity miles/hour	4	3-4	3-8	4-2
sky	blue	blue-cloudy	blue-cloudy	overcast
Rainfall at test	nil	nil	nil	nil
Previous 24 hours	trace	nil	nil	trace

### d. Toxicological Results.

#### 1. Physiological Observations:

1. Physiological Observations									
No.	Position	No. of	Casualties			Percentages		Remarks	
of		goats	Dead in	Severe	Slight	Dead	Severe		
trial		used	48 hrs.	Class	Class	casual-			
						ties and			
						Dead			
1	In trench	10	3	6	1	30	90	Of 11 rats, 10 died	
	" dugout	1	0	1	0	0	100	1 rat which died	
	" open at								
	50 yards	5	0	0	4	0	0	Of 4 rats, 1 died	
	at 100 "	5	0	0	3	0	0	" 5 " 0 "	
2	In trench	7	4	2	1	57	86	Of 7 rats, 3 died	
	" dugout	1	1	0	0	100	100	Of 1 rat, 1 died	
	" open at								
	50 yards	5	0	3	2	0	60	Of 2 rats, 2 died	
	at 75 "	4	0	0	4	0	0	Of 4 rats, 3 died	
3	" 100 "	3	0	0	2	0	0	Of 2 rats, 2 died	
	" 130 "	-	-	-	-	-	-	Of 3 rats, 0 died	
	In trench	6	0	2	3	0	56	Of 7 rats, 5 died	
	" dugout	1	0	0	1	0	0	Of 1 rat, 0 died	
	" open at								
4	50 yards	5	0	0	2	0	0	Of 3 rats, 2 died	
	at 75 "	4	0	0	3	0	0	Of 4 rats, 1 died	
	at 100 "	5	0	0	2	0	0	Of 5 rats, 0 died	
	at 130 "	-	-	-	-	-	-	Of 3 rats, 0 died	
	5	In trench	7	5	1	1	71	86	Of 7 rats, 2 died
" dugout		1	1	0	0	100	100	1 rat which survived	
" open at									
50 yards		5	1	0	3	20	20	Of 5 rats, 0 died	
at 75 "		4	0	1	2	0	25	Of 4 rats, 1 died	
6	" 100 "	3	0	0	2	0	0	Of 3 rats, 0 died	

2. Observations on travel of clouds

- Exp. 1. 30 minutes after - 3500 yards from trenches.
- Exp. 2. 1700 yards - test paper turned.
- Exp. 3. 2500 yards - detected by odor and test paper.
- Exp. 4. 2500 yards - detected by odor and test paper (20 minutes after).

Experiment 1: Dense white cloud formed - spread S.E. at end of shoot. At 1200 yards - Sufficient phosgene present to turn test paper yellow - strong odor to lachrymation. At 1400 yards - Unprotected men coughed violently for 12-20 minutes.

Experiment 2: Opaque, dense cloud moved slowly from trenches, travelling S.E. - visible 5 minutes after shoot 1000 yards away. A pool of vapor, 40 yards in diameter seen in depression 500 yards east of trenches, an observer 12 minutes after end of shoot entered this pool. Sufficient phosgene present to irritate nostrils and gave taste for 2-3 hours. 2 observers at boundary of ground (1500 yards to 1700 yards) from trenches - distinct lachrymation - test paper turned yellow - tobacco reaction given. Cloud visible 20 minutes after shoot and up to at least 1000 yards beyond boundary fence.

Experiment 3: Cloud - S.W. direction - visible for distance of 300 yards. Limit for detection of phosgene 250 yards.

Experiment 4: Dense white cloud - moved north. Visible at 2500 yards for 2 observers, 2800 yards for third observer. At end of 20 minutes, not detected by odor, just noticeable by test paper. Portion of cloud remained behind and hung stationary over ground. (1400 yards from trenches). At end of 25 minutes large quantities of phosgene present.

Concentration of phosgene (no attempt made to analyze the stannic chloride present but total chlorides were calculated as phosgene).

Position	Time after burst 1st shell when sample was taken		Height above floor of trench at which sample was taken		Concentration	
	Minutes	Seconds	Feet	Inches	Mg./liter	Volume of air containing 1 vol. phosgene both at N.T.P.
5	1	0	4	0	1.06	4270
9	"	"	"	"	.54	5380
11	"	"	"	"	.57	7940
4	2	30	"	"	5.71	753
8	"	"	"	"	3.08	1470
14	"	"	"	"	1.50	3020
15	"	"	1	8	.63	7190
5	4	30	4	0	3.04	1490
10	"	"	"	"	4.25	1060
15	"	"	"	"	.19	23800
6	"	"	1	8	45.01	98
12	"	"	"	"	0.27	16900
1	5	15	4	0	0.48	9430
7	"	"	"	"	0.92	4920
8	"	"	1	8	0.22	20600
16	"	"	"	"	2.06	2200
dugout (above floor of dugout).						

### c. Effects on Animals:

No. of trial	No. goats used	% Killed	% Severe casualties including killed
1	11	37	91
2	8	62	87
3	7	0	29
4	8	75	87

### e. Comparison of C.B.R. II with C.B.R. I.

Concentrations obtained in case of C.B.R. II of same general order as average concentrations on all phosgene tests with 4.5" howitzers. As regards lethal properties of Mark I and Mark II - nothing to show which is more toxic. In former case 24 goats in all have been killed out of 60 used, in latter 13 out of 31 (40 and 42% respectively).

f. Conclusions:

No marked difference between efficiency of Mark I and Mark II.

Criticisms: G.B.H. Mark I and Mark II are phosgene-arsenic trichloride mixtures.

42. C.O.P. #19. (1679)

Report on firing trial of 4.5" Howitzer shell, container type, filled - phosgene and arsenic trichloride.

a. Object:

To determine number of shells filled C.B.R. required in a given front.

b. Comparison of 3 Experiments.

Date	May 8, 1917	Mar. 1, 1917	Mar. 1, 1917
Time of day	5:40 P.M.	10:30 A.M.	5:00 P.M.
No. and type of guns used	2-4.5" hows.	3-4.5" hows.	3-4.5" hows.
Type of shell	steel container	steel cont'r.	steel cont'r.
Map range, yards	1750	1750	1750
Front engaged, yards	40	40	40
Effective area, yards	40 by 30	40 by 30	40 by 30
Rounds fired	50	50	50
Rounds in effective area	29	30	26

c. Comparison of 6 tests.

No. of experiment	1	2	3	4	5	6
Date	Feb. 21, 1917	Feb. 21, 1917	Feb. 21, 1917	Mar. 1, 1917	Mar. 1, 1917	Mar. 1, 1917
Time of day	1 P.M.	6 P.M.	4 P.M.	10:30 A.M.	3 P.M.	8 P.M.
Barometer, inches	29.60	29.67	29.85	29.95	29.91	29.91
Thermometer, wet bulb °F.	45.	43.1	43.4	40.8	41.6	41.6
" dry " "	45.	47.2	44.	43.	43.7	43.7
Wind direction	N.E.-E	N.N.E.	W.S.W.	N.N.W.	N.E.	---
" velocity miles per hour	2-4	1-2	9-10	3	2	nil
Sky	overcast	overcast	overcast	overcast	overcast	overcast
Rainfall	nil	nil	nil	nil	nil	nil
" previous 24 hours	0.12"	0.12"	0.11"	trace	trace	trace
<u>Artillery Observations</u>						
Type of shell container	steel	steel	steel	steel	steel	steel
No. of 4.5" how.	3	3	3	3	3	3
Map range, yards	1750	1750	1750	1750	1750	1750
Front engaged, yards	20	20	20	40	40	40
Size of effective area, yds.	20x30	20x30	20x30	40x30	40x30	40x30
No. of rounds fired	25	25	50	50	75	50
Rounds in area	13	9	23	30	43	25
Rate of fire B.F.	6 sec.	6 sec.	6 sec.	3 sec.	3 sec.	3 sec.
Total time to fire	---	2 min. 55 sec.	3 min. 35 sec.	7 min. 2 sec.	---	5 min. 30 sec.
Accuracy of shooting	good	fair	poor	very good	good	good
Costs used	10	9	---	7	10	4
No. dead in 48 hours	3	3	---	2	7	4
Rabbits used	9	5	14	7	10	9
No. dead in 48 hours	3	1	1	1	2	9
Rats used; died 48 hours	6/7	4/5	---	4/7	---	2/2
Mice " ; " " "	---	---	---	7/7	9/9	7/7
% died, all animals	53.8	44.4	7.1	50.0	62.1	100

Remarks: Trial No. 3 wind too high - trial no. 5 conditions ideal.

Rate of fire	3 sec.	5 sec.	5 sec.
Time taken to fire all rounds	6 min. 2 sec.	7 min. 2 sec.	5 min. 30 sec.
Wind velocity, miles per hr.	7-15	5	inappreciable
Animals killed, percent	0	50	100
Liters of liquid from effective shell per yard of front per minute	0.11	0.1	0.11

#### d. Conclusions.

Experiment 1 compared with 2 and 3, shows that with a wind varying between 7 and 15 miles per hour no effect is likely to be produced.

In experiment 1, 12 goats were placed in the trench at about 5 yard intervals, but none were killed, 2 where direct hits were made were affected, 1 having severe respiratory distress for 4 days.



43. Kuhn, Richter, Lovenhart, Burrell, Clayton, Webster.  
D.M. XVII-29.

Preliminary pharmacological report on field test. Mustard  
Gas and Ammixtures. Test made August 21, 1918.

a. Object:

Toxicity on dogs of pure mustard gas, crude mustard gas,  
pure mustard gas plus 15% phosgene, and pure mustard gas plus 15% chlor-  
benzol, when exploded from 75-mm shells.

Purity of pure mustard - 96.08%; of crude mustard 86.75%.

b. Method:

Four fields used - fields lying perpendicular to wind  
direction.

Twenty-four 75 mm gas shells in each group; 6 rows of 4  
shells each; rows 40 feet long and 4 feet apart--shell banks 100 feet  
apart. Each group fired in banks of 4 shells each. Shell laid on ground  
with their noses inclined slightly downward. Interval between firing  
of each group - 10 seconds.

Animals - 20 dogs in front of each shell bank; 5 rows,  
4 dogs each--each row 60 feet long, 13.7 ft apart--dogs fastened by 3-ft.  
chains. Front row-20 feet from front line of shell. Rear row-75 feet  
from front line of shell.

Period of exposure - 10 A.M. to 1 P.M.

All shells filled to 7/8 vol. (415 cc.) - fitted with  
regular Mark IV loaded boosters and adapters.

c. Metereological Data:

Weather - clear, warm sun

Wind - 4 1/2 miles per hour at firing, ave. 6 mi./hr. for 1 hr.

Temp. - Air 81°F., ground 89°F., wet bulb 69°F.

Relative humidity - 54%.

Pressure - 30.08 inches.

Sampling intervals - 1, 2, 3, 4, 5 min. from front row to back.

d. Analytical Data:

Mg. per liter total chlorides.

Pure Mustard			Crude Mustard			Pure mustard & 15% phosgene			Pure mustard & 15% chlorbenzene		
a	b	c	a	b	c	a	b	c	a	b	c
.10	.12	.12	.12	.08	.11	.18	.28	.14	.18	.11	.11
.08	.09	.27	.12	.12	.09	.47	.12	.14	.11	.09	.07
.11	.07	.06	.13	.18	---	.10	.14	.18	.12	.15	.12
.05	.08	.09	.08	.08	.13	.11	.09	.07	.16	.00	.09
.08	.06	.06	.10	.27	.08	.10	.12	.07	.13	.12	.10

Fragmentation -

Pure mustard - 6 poor, 18 good

Crude mustard - 5 failed, 11 poor, 8 good

Mustard plus 15% phosgene - 2 failed, 14 poor, 8 good

Mustard plus 15% chlorbenzene - 18 poor, 11 good.

e. Results:

Pure mustard gas plus 15% phosgene.

Died 69 hours	Died 21 hours	Died 18 hours	Died 22 hours
Died 95 "	Died 21 "	Died 54 "	-----
Died 46 "	Escaped	Died 8 days	-----
Died 45 "	Died 8-1/2 days	Died 26 "	-----
Died 7 days	-----	-----	Died 19 days

f. Summary:

- To date the mortality on each group is:
 

pure mustard plus phosgene	-	70%
Pure mustard	-	55%
Pure mustard plus chlorbenzene	-	30%
Crude mustard	-	40%
- During exposure animals exposed to mustard and phosgene were more depressed than those of other groups.
- Mixture groups showing earliest deaths - rank
  - 1st. Phosgene and mustard, 5 deaths in 48 hours.
  - 2nd. Chlorbenzene and mustard, 3 deaths in 48 hours.
  - 3rd. Crude mustard, 1 death in 48 hours.
  - 4th. Pure mustard, no deaths in 48 hours.
- Low mortality with crude mustard partly due to poor fragmentation.

44. Kuhn and Kolls.  
P.T. VIII-1387.

a. Object:

Comparison of the toxicity of (1) pure mustard, (2) crude mustard, (3) pure mustard containing 15% of phosgene and (4) pure mustard containing 15% chlorobenzene, when used as fillers in 75 mm. shell fired statically under field conditions, Sept. 16, 1918.

b. Methods:

1. Shell banks - 24 shell each, line perpendicular to wind - 180 feet apart.

2. Shell fillings -  $\frac{7}{8}$  vol. - 415 cc. of filled. Marx IV booster - 30 gms. T.B.T., 10 gms. tetryl.

Field A - pure mustard with 15% chlorobenzene

" B - pure mustard with 15% phosgene

" C - crude mustard (63% pure)

" D - pure mustard (96.25% pure)

3. Location of shell.

(a) 24 shell in each field.

(b) 6 rows, 4 shell each.

(c) Distance of rows - 4 ft. apart from each group 40 feet

(d) Position of shell - nose inclined slightly downward

(e) Order of firing - each group fired banks of 4 shell at 10 sec. intervals; corresponding banks in each group were fired simultaneously.

4. Location of animals.

20 dogs in front of each group of shell - 5 rows, 4 dogs in each row, rows 13 $\frac{1}{2}$  ft. apart, distance from line of shell to front row 20 ft., rear row 75 ft.

5. Exposure:

- (a) Toxicity test - 11:15 A.M. to 3:15 P.M.
- (b) Persistence, in positions 1 and 4, of the first row 4:30 P.M. to 10:30 P.M.
- (c) Persistence, in positions 2 and 3 of the first row 23 hrs. after firing - 10:15 A.M. to 4:15 P.M.

c. Meteorological Data:

Weather - mild, warm day, light clouds  
 Wind - 5.1 miles per hour at time of firing  
       5.8 miles per hour, ave. velocity for 1 hr. after firing  
 Temperature - air - 79° F.  
               ground - 80.6° F.  
               wet bulb - 68.2° F.  
 Relative Humidity - 53%  
 Pressure - 29.67 inches  
 Direction of Wind -  
     Time of firing - right angles to field  
     10 min. later - veered to left  
     during first hour - varied between right angles and left inclination.  
     Probably accounts for more deaths in left of field.

d. Toxicological Data:

(1) Field B - Pure mustard and phosgene.

Dead 111 hrs.	Dead 220 hrs.	Dead 15 days	
Dead 100 "	Dead 208 "	Dead 25 days	
Dead 15 "	Dead 200 hrs.	Dead 211 hrs.	Escaped
Dead 38 "	Dead 8 hrs.	Dead 252 hrs.	
		Dead 41 hrs.	

Shell

Row	1	2	3	4	5
No. died	5	5	5	5	1
No. killed					
for autopsy	1 (21 days)	1	0	1	

(2) Field B - Persistence Test.

Length of exposure, hours	6	6	6	6
Time after firing shell, hours	6	6	25	25
Position of dogs	1-1	1-4	1-2	1-3

(3) Total Number Casualties.

Pure mustard and phosgene - 13 deaths, 2 sev. 4 light casualties  
 " " " chlorobenzene - 15 " , 3 " 2 " "  
 Crude " - 15 deaths, 5 light casualties  
 Pure mustard - 12 deaths, 1 severe, 5 light casualties

(4) Time of death.

Crude and pure mustard, earlier deaths than produced by admixtures.

Time of death within	Pure mustard chlorbenzene	Pure mustard phosgene	Crude Mustard	Pure Mustard
48 hours	3	3	5	4
72 "	5	3	9	8
144 "	5	5	11	9
288 "	12	11	15	11
3 weeks	15	11	14	12

e. Conclusions

1. From standpoint of toxicity.

- (a) Little difference between crude mustard and pure mustard and chlorbenzene.
- (b) Little difference between pure mustard and pure mustard and phosgene.
- (c) Crude mustard predominates slightly over pure mustard.

2. From total number casualties - rank

- 1st. Pure mustard plus 15% chlorbenzene
- 2nd. Crude mustard
- 3rd. Pure mustard plus 15% phosgene
- 4th. Pure mustard

3. From standpoint of persistence

- (a) Six hours after firing of shells - rank
  - 1st. Pure mustard plus 15% chlorbenzene
  - 2nd. Crude mustard
  - 3rd. Pure mustard plus 15% phosgene
  - 4th. Pure mustard.
- (b) Twenty-three hours after firing of shell -rank
  - 1st. Chlorbenzene admixture
  - 2nd. Crude mustard
  - 3rd. Pure mustard
  - 4th. Phosgene admixture (rapid drop in concentration).

45. Kolls and Kuhn.  
B.E. XXVIII-90.

Toxicity on dogs of 50% carbon monoxide and 50% phosgene.

a. Object:

To determine effects on dogs of a cloud consisting of 50/50 mixture carbon monoxide and phosgene from cylinders.

b. Method:

50 lb. mixture of gas from each of 2 cylinders - 20 feet apart.

Length of exposure - 30 min. (actually exposed to gas about 2 minutes. H.A.K.)

Position of dogs:

1. Five dogs, 20 ft. intervals, 40 ft. from cylinders
2. Seven dogs, 20 ft. " 100 " " "
3. Six dogs, 50 ft. " 200 " " "

c. Discussion:

1. Time for complete discharge of cylinders  
(a) Left - 1 min. (b) Right - 2 min.
2. Wind  
(a) Direction - right angles to field  
(b) Velocity - 7 to 8 miles per hour.

d. Results:

1. First row:  
All showed depression, conjunctivitis, lachrymation  
dyspnoea.  
Center dog and one left of center:  
(a) immediate vomiting  
(b) death within 24 hours.
2. Second row:  
Five central dogs: lachrymation, slight dyspnoea,  
depression.  
End dogs unaffected.  
All normal in 48 hours.
3. Third row:  
Three central dogs: lachrymation  
End dogs: unaffected  
All normal in 48 hours.

---

e. Conclusions

1. Effect of mixture less than equal amount of either. arsine or phosgene on dogs under similar conditions.
2. Area of lethal concentration.  
40 feet from cylinders along center line  
20 feet to left.

46. Richter, Bruce, Smith, Loewenhart and Kolls.  
S.M. XXIX-76.

a. Object:

To determine toxicity of a 50-50 mixture of phosgene and chlorine when used in the mobile gas unit, under field conditions.

b. Methods and Details:

Two cylinders, 30 lbs. each, of the mixture used. Animals and cylinders arranged as in diagram in original report. Time of exposure 30 minutes.

Amount of gas discharged from cylinder I - 30 lbs.

" " " " " " " " II - 30 "

Time of discharge from cylinder I - 55 seconds complete

" " " " " " " " II - 55 seconds with nozzle,

20 seconds without.

Note: Approximately .75% of total amount of toxic material was discharged in the 55 second period.

c. Metereological Data:

Wind - 7 - 8 miles per hour.

Temperature of air - 61° F.

" " " " ground - 58.4° F.

Barometer - 29.75 inches

Relative humidity - 42.5%

Clear, bright sunshine.

d. Field Results:

Time	Sample No.	Concentration Ml./l.	
		Total Chlorine	Free Chlorine
4 sec.	A. 1	0.25	0.00
10 "	2	0.07	
30 "	3 a	---	0.00
30 "	3 b	0.10	
1 min.	4	0.00	
2 "	5	stopcock leaked	
4 sec.	B. 1	12.70	
10 "	2	3.52	
30 "	3 a	---	0.09
30 "	3 b	1.55	
1 min.	4	4.57	
2 "	5	0.02	



Time	Sample No.	Concentration Mg./l.	
		Total Chlorine	Free Chlorine
4 sec.	G. 1	0.16	
10 "	2	2.89	
30 "	3 a	---	5.07
30 "	3 b	6.68	
1 min.	4	0.55	
2 "	5	0.26	
4 sec.	D. 1	0.60	
10 "	2	0.48	
30 "	3 a	---	0.00
30 "	3 b	0.00	
1 min.	4	0.00	
2 "	5	0.34	
4 sec.	E. 1	0.54	
10 "	2	0.10	
30 "	3 a	---	0.00
30 "	3 b	0.00	
1 min.	4	0.00	
2 "	5	0.25	
4 sec.	F. 1	0.57	
10 "	2	0.25	
30 "	3 a	---	0.06
30 "	3 b	0.59	
1 min.	4	0.76	
2 "	5	0.00	
4 sec.	G. 1	0.10	
10 "	2	0.10	
30 "	3 a	---	0.00
30 "	3 b	0.54	
1 min.	4	0.24	
2 "	5	0.34	
4 sec.	H. 1	0.00	
10 "	2	0.00	
30 "	3 a	---	0.00
30 "	3 b	0.00	
1 min.	4	0.09	
2 "	5	0.01	
4 sec.	I. 1	0.01	
10 "	2	0.09	
30 "	3 a	---	0.00
30 "	3 b	0.01	
1 min.	4	0.80	
2 "	5	0.00	

Time	Sample No.	Concentration M./l.	
		Total chlorine	Free chlorine
4 sec.	J. 1	0.25	
10 "	2	0.22	
20 "	3 a	---	0.00
20 "	3 b	0.00	
1 min.	4	0.30	
2 "	5	0.00	
4 sec.	K. 1	0.00	
10 "	2	0.00	
20 "	3 a	---	0.00
20 "	3 b	0.05	
1 min.	4	0.97	
2 "	5	0.10	

e. Toxicological Results:

Dogs exposed for 20 minutes -

All dogs in 1st row showed depression, conjunctivitis, lachrymation, dyspnoea. 2 dogs vomited.  
 Five dogs in center showed lachrymation, slight dyspnoea, and depression.  
 Dog on either end of row unaffected.  
 In third row, dog to left of center and 2 dogs to right of center showed lachrymation. Other dogs unaffected.

In 24 hours dog in center of 1st row - dead.  
 In 24 hours dog to left of center of 1st row - dead.  
 In 24 hours other dogs center of 1st row - depressed, recovered in 48 hrs.  
 In 24 hours all dogs in 2nd row - normal in 48 hours.

f. Conclusions:

Lethal concentration for dogs was produced in 1st row from center dog to dog 20 feet to left of center.

All dogs in 1st row (20 ft.) incapacitated.

Effect of mixture much less than an equal amount of arsine or phosgene discharge under similar contents in same position.

47. C.C.P. 242. (3965)

Phosgene, arsenious chloride, chlorpicrin and stannic chloride.

Summary of maximum persistencies for various chemical fillings in shell,  
bombs and drums.

Filling	Over surface	Under surface	Covered Sur- face	Travel of cloud
Phosgene	15 min. in curator, Livens: drum C.C.P. 2326	Mil. C.C.P. 2423	14-5 hrs., 2-4 Stokes, also 12-2" T.M. bombs exploded in trench C.C.P. 2423	1800-2250 yards 50-4.5" how. shell C.C.P. 2570
Phosgene and chlorpicrin	2-5 hrs. ob- servers erect 20-22 hrs. ob- servers stoop- ing C.C.P. 2549	200 hours C.C.P. 2540	16 hrs. 2-4" Stokes bombs trench C.C.P. 2125 16 hrs. 50-4.5" howitzer shell C.C.P. 2539	2000 yds. at 2000 yds. severe lachrymation from 50-4.5" howitzer shells C.C.P. 2539
Phosgene arsenious cl. and phosgene: stannic cl.	mil. C.C.P. 2269	mil. C.C.P. 2269	30 min. minimum 2-4.5" how's. exploded in trench C.C.P. 2938	3500 yds. traces of phosgene de- tected, very marked at 1400 yds., 50-4.5" how. shell C.C.P. 2348

# XIV. BIBLIOGRAPHY.

## Effect on Animals:

<u>B.M.</u>	<u>P.T.</u>	<u>O.C.P.</u>	<u>O.W.C.</u>
I-29	VIII-A385	42	50
VII-50	VIII-A386	74	67
XIV-63-1	VIII-A388	107	78
XIX-74	VIII-A389	108	110
XXI-76	VIII-A393	178	
XXIII-138		208	
XXVIII-90-8		216	
XXIX-73		221 (3770)	
XXXII-57		228	
		241	

## Effect on Man:

Ph. 1, 4, 13, 17, 20, 21, 40, 53

B.M. IX-35

A.E.F. 66, 48-4-5

O.C.P. 148 (6064)

H.D.D. 3

P.R. V-220

A.P.M. 34-9-No. 7

## Effect on Animals and Man:

<u>B.M.</u>	<u>P.T.</u>	<u>O.C.P.</u>	<u>O.W.C.</u>	<u>A.E.F.</u>	<u>C.L.</u>	<u>A.G.</u>	<u>Z.</u>	<u>P.S.</u>
XXVII-84-	VII-A348	2	51	176	18	21	83-A	XXIV-II-23
12-39	VIII-A351	3	54				550	XXXIX-39
XXVIII-90-	VIII-353	6	55				607	
10	VIII-A355	29	64					
XXIX-76	VIII-A387	178	77					
XXIV-66	VIII-A390	217	89					
XXVI-28	VIII-A398	219	95					
		242						

Field Tests (Phosgene Alone).

B.H.	P.T.	PH	Z	H.D.D.	
XXVII-48	II-A127	1	30-2	3	J.H.M. 33
XXVII-90	VIII-A385	2	30-11	45	C.W.H. XII-part II
XXIX-75	VIII-A386	36	30-12	46	E.A.C.D. 101
XXX-63	VIII-A388	57	30-34	58	M. Ph. 28 and 29
XXX-64	VIII-A389	40	30-39		
XXX-64		44	30-44		
XXX-78		46	275		
XXXI-93		53			
XXXV-60		64			
		75			
		87			
		97			
		98			
		114-120			
		115			
		129			
		134			

Literature compiled by:

R.E. Morse

M.D. Craighill.

Author:

R.E. Morse.

Supervised by:

Harry A. Kuhn  
Harry A. Kuhn,  
1st Lieut. C.W.S., U.S.A.,  
Chief, Dept. of Toxicology.

Approved by:

Edward B. Vedder  
Edward B. Vedder,  
Lieut. Col., M.C., U.S.A.,  
Chief, Medical Research Div.

Digest of Reports Concerning the  
toxic Effects of Phosgene on Man  
& the Laboratory Animals.  
1.

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and; men)



DEPARTMENT OF THE ARMY  
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND  
EDGEWOOD CHEMICAL BIOLOGICAL CENTER  
5183 BLACKHAWK ROAD  
ABERDEEN PROVING GROUND, MD 21010-5424

REPLY TO  
ATTENTION OF

RDCB-DPC-RS

15 October 2015

MEMORANDUM THRU Director, Edgewood Chemical Biological Center, (RDCB-D/Dr. Joseph Corriveau), 5183 Blackhawk Road, Aberdeen Proving Ground, Maryland 21010-5424

FOR Defense Technical Information Center, 8725 John J. Kingman Road, Ft Belvoir, VA 22060

SUBJECT: Internal Request for Change in Distribution

1. This action is in response to an Edgewood Chemical Biological Center (ECBC) Internal Request for a Change in Distribution for the following documents as listed in attachment.
2. The listed documents have been reviewed by ECBC Subject Matter Experts and deemed suitable for the change in distribution to read "Approved for public release; distribution unlimited."
3. The point of contact is Adana Eilo, ECBC Security Specialist, (410) 436-2063 or [adana.l.eilo.civ@mail.mil](mailto:adana.l.eilo.civ@mail.mil).

Encl

  
RONALD L. STAFFORD  
Security Manager

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